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RESEARCH AND TECHNOLOGY

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ANNUAL REPORT OF THE LANGLEY RESEARCH CENTER

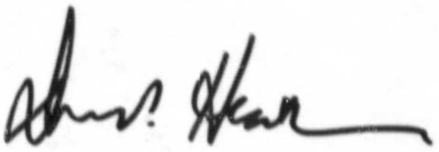
NASA
National Aeronautics and Space Administration

Langley Research Center
Hampton, Virginia 23665

INTRODUCTION

This Langley Research Center Annual Report on Research and Technology accomplishments for 1980 contains highlights of our major accomplishments and applications made during the past year. The highlights illustrate both the broad range of the research and technology activities at the Langley Research Center and the contributions of this work toward maintaining the United States' leadership in aeronautics and space research.

Results of Langley research and technology are made available to users through the NASA scientific and technical information system. The research output of the Langley Research Center is listed by title in an annual compilation entitled "Scientific and Technical Information Output of the Langley Research Center." The compilation for calendar year 1979 contains 1364 items and is available on request from The Report and Manuscript Control Office, Mail Stop 180A, Langley Research Center, Hampton, Virginia 23665 (827-2301).



Donald P. Hearth
Director

CONTENTS

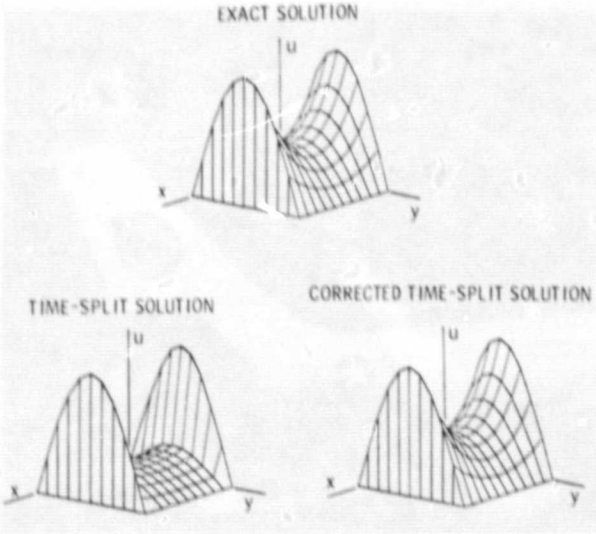
Note: The research and technology accomplishments in this report are arranged according to the NASA program office sponsoring the work and according to the Agencywide Research and Technology Objectives and Plans (RTOP) work breakdown structure. For additional information on any highlight, contact the individual identified with the highlight. Commercial telephone users may dial the listed extension preceded by (804) 827. Telephone users with access to the Federal Telecommunications System (FTS) may dial the extension preceded by 928.

Aeronautics and Space Technology

Accuracy of Time-Split Finite-Difference Schemes

Recent theoretical work has proven that implicit time-split finite-difference schemes are unconditionally stable for the 3-D Navier-Stokes equations. It was found that time-split methods, in general, possess two serious errors, one due to the temporal inaccuracy associated with the splitting and one due to the incompatibility of the split steps with the boundary data. In effect, the process of time splitting leads to the solution of a modified differential equation subject to modified boundary data. In order to improve the accuracy of the time-split scheme, an explicit corrector step was devised which exactly eliminated both sources of error at minimal computational cost. Inclusion of the corrector step produced a scheme with temporal and spatial accuracy comparable to alternating direction implicit methods. Shown in the figure are solutions to Laplace's equation on the unit square subject to Dirichlet boundary data. The numerical solutions were obtained as the asymptotic steady state of the heat conduction equation using the standard time-split method and the new corrected time-split method. The figure shows the exact analytic solution along with the two computed solutions run at a time step 100 times larger than the explicit stability limit. Comparison of the solution illustrates the improvement in accuracy obtained with the corrected method.

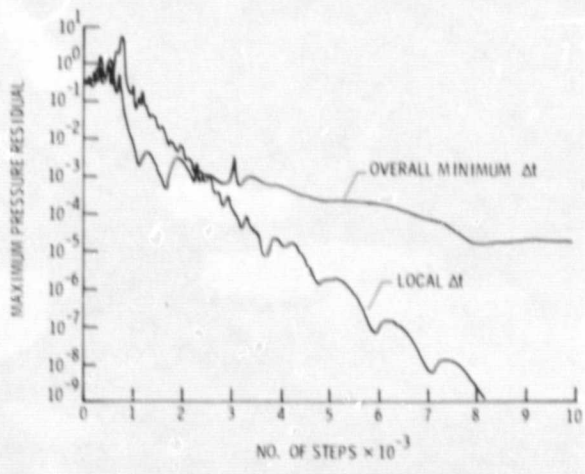
Douglas L. Dwoyer, 2627 (505-31-13)



Solution of $\partial^2 u/\partial x^2 + \partial^2 u/\partial y^2 = 0$

Numerical Solution of the Euler Equations in the Transonic Regime

A joint in-house and contractual research effort is underway to obtain fast and accurate solutions of the Euler equations for transonic flows about airfoil shapes. To test the accuracy of the numerical algorithms, their convergence rate, and the implementation of boundary conditions, the flow about a circular cylinder has been used as a test case. The test problem has brought to light some serious problems with existing algorithms which do not show up as clearly when the methods are applied to slender airfoil shapes. The most serious problems are very slow convergence rates, poor accuracy near stagnation points, and the appearance at supercritical speeds of a recirculation bubble in the neighborhood of the rear stagnation point which cannot be explained on the basis of the



Comparison of convergence rate using the overall minimum Δt and the local value of Δt

damping inherent in the numerical algorithm. The slow convergence rate has been alleviated by using the local time step for the computation of each grid point; the improvement is shown in the figure. This particular calculation was made with a vector code written for the CYBER 203 computer which runs 45 times faster than its scalar counterpart on the CYBER 175.

Manuel D. Salas, 2627 (505-31-13)

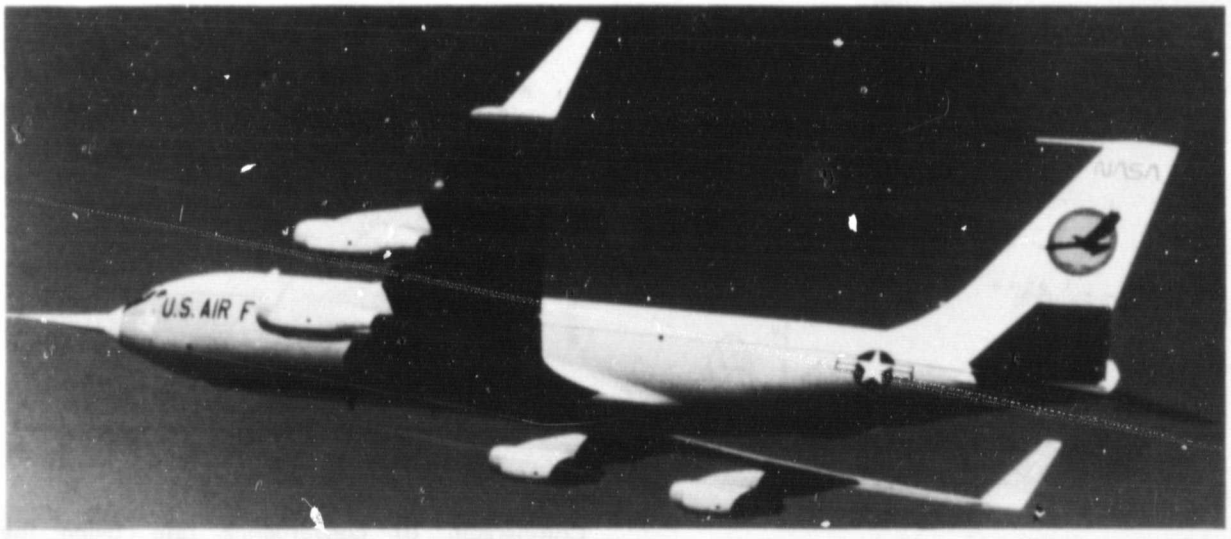
Transonic Flow Calculations on the CYBER 203 Computer

The CYBER 203 computer at Langley Research Center is a vector processor which is very efficient when operating on algorithms which are vectorizable. One such algorithm which has been developed for transonic flow calculations is the "Zebra" algorithm. This algorithm was developed and tested on a pilot code which calculated transonic flow over a swept wing using the artificial density formulation. The Zebra algorithm has now been incorporated into an existing production code (FLO-22). This code uses a nonconservative form of the full-potential equation and a parabolic coordinate system for 3-D transonic flow over isolated wings. The original code used a successive line overrelaxation (SLOR) algorithm and ran at a computational rate of about 6200 points per second on a CYBER 175 conventional-type computer. The new version of the code with the Zebra algorithm runs at a computational rate of about 62,000 points per second on the CYBER 203 computer. Not all of this increase in computational rate is due to the change in algorithm. The new CYBER 203 has a very fast scalar unit; and, when its optimizing compiler is used, it can run scalar codes quite efficiently. Also, computation rate is not the only factor to be considered in choosing an algorithm — convergence rate is also very important. The tests on the pilot code showed that the convergence rate of the Zebra algorithm was about the same as SLOR for that case. Tests are currently underway to determine if its convergence rate will be as good with the nonconservative formulation used in the original code.

James D. Keller, 2627 (505-31-13)

Winglets

Winglets are small, nearly vertical aerodynamic surfaces which are designed to be mounted at the tips of aircraft wings. They are found in nature on all soaring birds, which cant their tip feathers when attempting to achieve a high-lift flight condition. Design optimization studies and wind-tunnel tests at Langley have shown that winglets can produce significant increases in the lift-drag ratios of some of today's transport aircraft. The application of winglets to an Air Force KC-135 tanker aircraft is predicted to increase its cruise lift-drag ratio by 7 to 8 percent. If retrofitted to the entire KC-135 fleet, the cost savings would be $1.4 billion over the fleet lifetime.



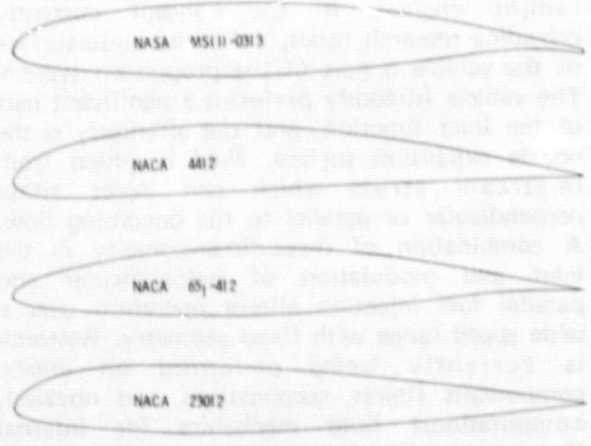
Test aircraft

Therefore, the Air Force and NASA have embarked on a joint program to obtain a full-scale evaluation of winglets on the KC-135 aircraft. The Boeing Company, under Air Force contract, has constructed a set of flight test winglets. The Dryden Flight Research Center has instrumented a test airplane. The winglets were installed on the flight-test aircraft in July of 1979, and 16 winglet research flights have been completed to date, with all flights scheduled for completion in the fall of 1980. These tests are providing an evaluation of the winglets throughout the flight envelope of the airplane. Preliminary data analyses indicate a 7.1-percent increase in cruise performance.

Stuart Flechner, 2631 (505-31-43)

Medium-Speed Airfoils

A new family of medium-speed airfoils has been developed for General Aviation applications. These airfoils were designed for aircraft such as turboprop business airplanes and commuter airplanes, whose cruise speeds are not high enough to require use of supercritical airfoils. These airfoils were developed by combining the best features of NASA's low-speed and supercritical airfoil technology. Thus, the new airfoils provide higher cruise Mach numbers than the low-speed airfoils, but retain good high-lift, low-speed characteristics. Cruise Mach numbers vary from about 0.66 to 0.72 for the airfoil family. The figure compares the airfoil shape of a 13-percent-thick medium-speed airfoil with several older



Comparison of airfoil shapes

12-percent-thick NACA airfoils. The new airfoils incorporate more camber in the rear of the airfoil than the NACA airfoils and thus the aft region of the airfoil carries more load. Several military and commercial aircraft have been proposed utilizing the new medium-speed airfoils.

Robert J. McGhee, 4514 (505-31-33)

Submicron Particle Generator for High Pressure Application

A particle generator has been developed which is not pressure limited as are most existing techniques. The technique was developed to provide seeding for laser velocimeters in high Mach number wind tunnels but has application to any need for submicron particles such as pollutant studies. The essential ingredient is extremely small fixed injection slits which are operated at a sonic, or choked condition. The increase in velocity between the micro-slit wall (Velocity = 0) and the center of the micro-slit (sonic velocity) provides a shear force large enough to break up agglomerates into individual particles. A tremendous advantage of this technique is a relative independence of ambient pressure level, i.e., particles can be generated even at high ambient pressures as required sonic condition is a function of pressure ratio and not pressure level. This technique is the only device capable of producing a cloud of uniform-sized submicron particles at high pressure and high flow rates.

E. Leon Morrisette, 3735 (505-31-23)

Microcomputer Programming Language

As microcomputers become more powerful and less expensive, they become increasingly useful to a wide range of NASA projects. Applications which would require a large number of hardware components can often be handled by a single microcomputer with suitable software.

Writing programs for microcomputers is usually a tedious process. The software support available often is limited to an assembler. Such is the case with the Intel 8748, which is an eight-bit microprocessor and memory packaged as a single integrated circuit.

To increase the usefulness of this device, a PASCAL-based high-level language called PASCAL/48 has been developed. The language closely resembles PASCAL with a few extensions to allow programmers to take advantage of the unique features of the Intel 8748. For example, facilities exist to control the allocation of data memory (an extremely limited resource on the Intel 8748) and to handle machine interrupts.

The PASCAL/48 compiler is a cross-compiler which executes on CDC CYBER 170 equipment producing an object module in the standard Intel format and a listing of the assembly language version of the machine instructions. A programmer can write PASCAL/48 programs substantially faster than writing equivalent programs in assembly language, and the resulting code is nearly as efficient.

PASCAL/48 is suitable for other products in the Intel MCS 48 series.

J. C. Knight, 3202 (505-31-83)

Grid Generation for Fluid Flow Computations

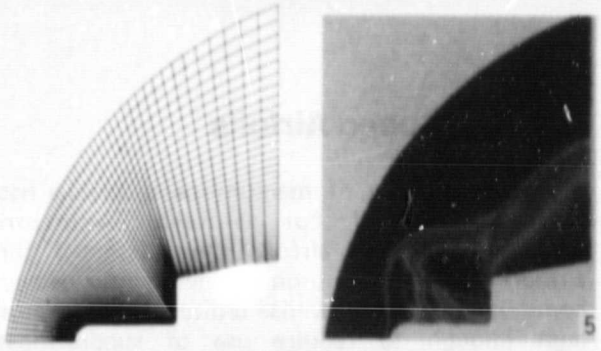
An algebraic grid generation technique has been developed and explored in conjunction with the solution of the Navier-Stokes equations for fluid flow. It is called the "two boundary technique" and has the potential for serving as the geometric foundation for flow field solutions in highly complex geometries. Two of the boundary surfaces are first represented by a grid structure having an equal number of nodes, then corresponding nodes on the two surfaces are connected by smooth, curved lines. The grid is completed by discretizing these lines. The Jacobian matrix of derivatives of the functions describing the resulting grid structure with respect to a rectangular cartesian system are computed directly, thereby permitting a transformation of the governing differential equations to a uniform rectangular grid.

This technique has been applied to the three-dimensional compressible Navier-Stokes equations in the region of a family of corner geometries where the flow is steady but characterized by strong shocks and three-dimensional separations; and also in the region of an axisymmetric spiked-nose body where the flow is oscillatory with a bow shock and separated flow.

The transformed equations have been solved by a computer program called the "Navier-Stokes Solver" running on the Control Data CYBER-203 vector computer. The program utilizes a technique based on the MacCormack time-split method and is written in the PASCAL based language using 32-bit arithmetic and storage to take full advantage of the speed and memory capacity of the CYBER-203.

The computed solutions are transferred back to the physical domain where they may be displayed through graphical techniques including color representation of the intensity of scalar variables. The figure shows the grid and computed density distribution over one plane for a spiked-nose body case.

Robert E. Smith, Jr., 3978 (505-31-83)



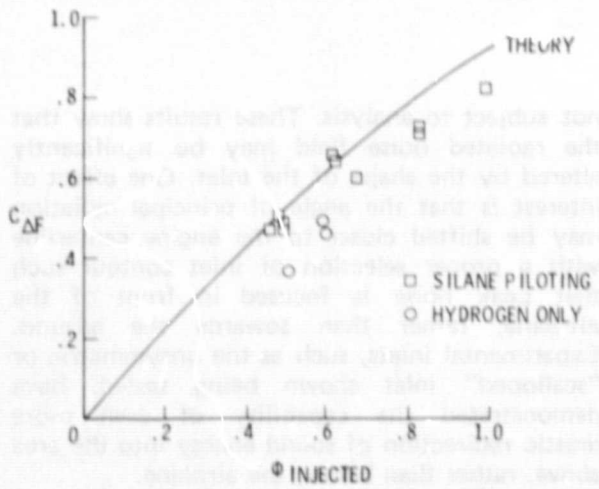
Grid Density distribution

Mach 7 Scramjet Engine Tests

A broad and comprehensive research program is currently underway at Langley to develop the technology for hydrogen-fueled, airframe-integrated, supersonic combustion ramjet engines. In the concept currently providing research focus, the entire undersurface of the vehicle is part of the propulsion system. The vehicle forebody performs a significant part of the inlet function, and the afterbody is the nozzle expansion surface. Fuel is added from in-stream struts which can inject either perpendicular or parallel to the oncoming flow. A combination of three-dimensionality in the inlet and modulation of perpendicular and parallel fuel injection allows operation over a wide speed range with fixed geometry. Research is currently being performed on engine components (inlets, combustions, and nozzles), computational fluid mechanics for internal flows, component integration (subscale engines), structures, and flow diagnostics.

Tests of the basic engine concept are being conducted at Mach 4 and Mach 7 to be representative of the lower and higher ends of the operational envelope. Preliminary testing was done in 1978 and 1979 to identify problems and component technology requirements. Results indicated reasonably good performance at low fuel-air ratios, but revealed problems in extending this performance to the higher fuel-air ratios necessary for flight. The major problem appeared to be achievement of proper ignition very near the point of fuel injection with sufficient release of heat in the initial portion of the combustor.

In subsequent Mach 7 tests, attempts to improve the performance at high fuel-air ratios have produced some very promising results. Two primary differences are responsible for the improvements. First, silane (SiH_4), a compound which readily ignites at room temperature, was used to provide a positive ignition source either as an ignitor (used only at start of test) or as a pilot (continuous throughout test). Second, an additional row of perpendicular fuel injectors was added downstream of the existing injectors. This provides a "stage interaction" which creates a relatively large-disturbance region to stabilize the flame and provide heat release near the fuel injectors. In these tests no attempt has yet been made to optimize either the staged injection or the use of silane to aid in ignition. The figure shows a plot of the recent results obtained. The curve is a target performance which is representative of an acceptable level for an actual aircraft application. Some of the data involve piloting with silane and some are for hydrogen fuel only after the silane ignitor was turned off. The piloted data at Mach 7 show performance of approximately 90 percent of the target; note that the hydrogen-only data have somewhat lower performance, but still about 80 percent of the target. This is true over a wide range of fuel-air ratios. The lower performance with hydrogen only is believed to be associated with poor fuel distribution. Since the desire is to use silane simply as an ignitor rather than a pilot, the challenge in remaining tests is to raise the fuel-air ratios with hydrogen while improving fuel distribution.



Engine performance with silane and staging

These new results are extremely encouraging. They show conclusively that excellent performance can be achieved in the engine concept under consideration, and imply even better performance for an optimized design.

Robert A. Jones, 3772 (505-32-93)

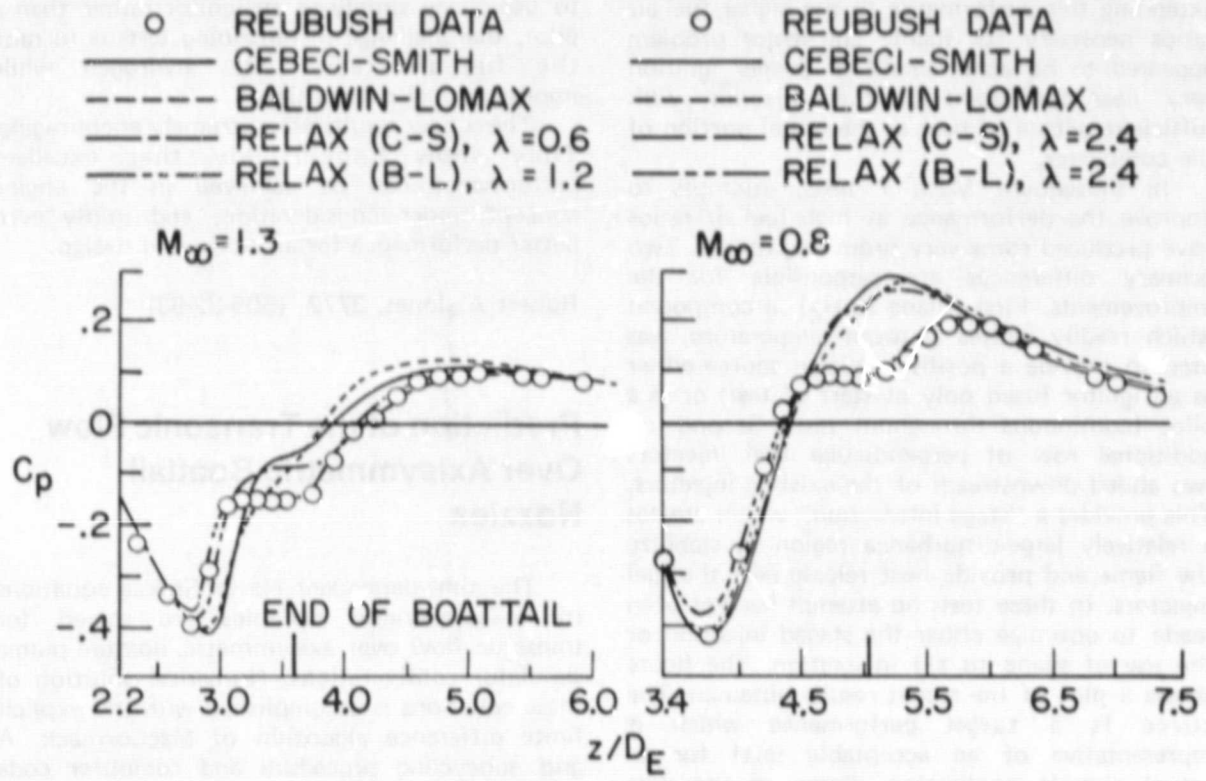
Prediction of the Transonic Flow Over Axisymmetric Boattail Nozzles

The time-dependent Navier-Stokes equations in mass-averaged variables are solved for transonic flow over axisymmetric boattail-plume simulator configurations. Numerical solution of these equations is accomplished with the explicit finite difference algorithm of MacCormack. A grid subcycling procedure and computer code vectorization are used to improve computational efficiency. The two-layer algebraic turbulence models of Cebeci-Smith (C-S) and Baldwin-Lomax (B-L) are employed for investigating turbulence closure. Two relaxation models based on these baseline models are also considered.

In this study solutions for the Reubush afterbody, which has a boattail terminal angle of 34^{o}, have been computed. For all cases the flow on the boattail is highly separated. The variation of the surface pressure coefficient C_p with the nondimensionalized axial distance z/D_E at the Mach numbers of 1.3 and 0.8 is shown in the figure. Results obtained with each of the four eddy viscosity models are given. The predictions with the baseline turbulence models show poor agreement with experiment. This is not surprising since these models do not account for upstream history effects. That is, if the flow is disturbed in some way (i.e., severe adverse pressure gradient) the turbulence field does not respond immediately. However, it does retain

memory of the event. The relaxation models attempt to account for this delayed response through a relaxation length scale (λ). The Relax (C-S) model solutions compare well with the data except for the separated flow region. In both the supersonic and subsonic cases the results determined with the Relax (B-L) model capture the pressure plateau region. These pressure distributions suggest that the relaxation turbulence models have potential to accurately predict such boattail flows.

R. C. Swanson, 2673 (505-32-13)



A comparison of pressure distributions using algebraic Eddy viscosity models

Engine Inlet Alters Noise Pattern

Systematic experimental and theoretical studies to understand the effect of inlet shape on the noise radiation from engine inlets have been conducted which lay the foundation for using inlet shape to control far-field engine noise. Starting with simple geometries that were amenable to analysis, experiments have been performed to verify the predictions. The results show excellent agreement in those cases where the noise source was well defined, even for variable cross-section geometries for which exact analytical solutions exist.

The experimental work has been extended to include the effects of flow and inlet shapes not subject to analysis. These results show that the radiated noise field may be significantly altered by the shape of the inlet. One effect of interest is that the angle of principal radiation may be shifted closer to the engine centerline with a proper selection of inlet contour such that peak noise is focused in front of the airplane, rather than towards the ground. Experimental inlets, such as the unsymmetric or "scalloped" inlet shown being tested, have demonstrated the capability of even more drastic redirection of sound energy into the area above, rather than below, the airplane.

Richard J. Silcox, 2617 (505-32-03)

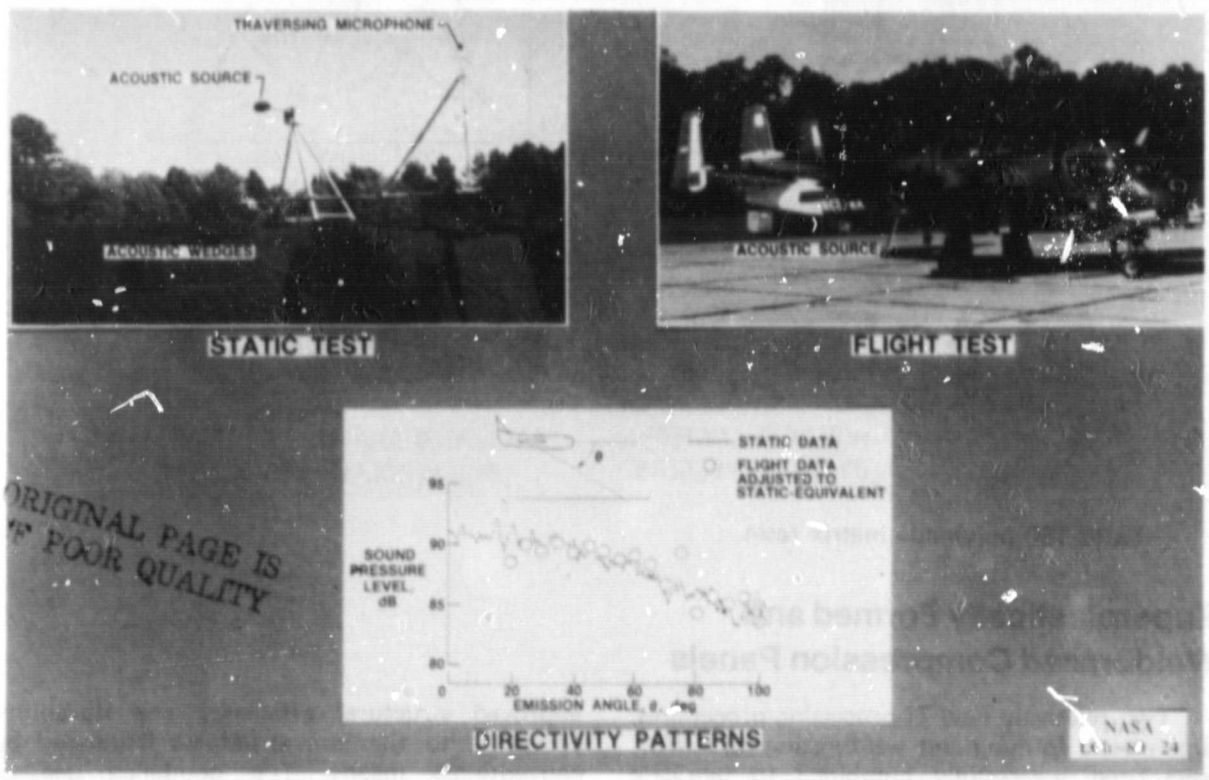
Flight Effects on Noise From Turbofan Engines

When a high by-pass ratio engine is tested on the ground and in flight, the noise produced is different in ways that are not always understood or predictable. An intercenter program involving engine test stand, wind tunnel, and flight tests on a small turbofan engine is in progress to improve the understanding of these differences and to develop techniques for simulating the flight effects on the ground. Two key results have been obtained in the past year.

The first result was obtained from a precursor flight test that verified procedures for static-to-flight comparisons and determined alterations to radiated noise patterns due to installation on the flight test airplane. The figure shows the noise source during ground calibration and on the flight vehicle, and a resulting data comparison. The ground test was performed at an outdoor test area with the ground covered by sound-absorbing wedges to minimize reflections. The source was a loudspeaker within a streamlined fairing. The airplane was then flown over an array of microphones with the source radiating at discrete frequencies. The acoustic data were processed by ensemble-averaging over the microphone array and adjusted to a static-equivalent condition. The adjustment procedure considers factors such as doppler frequency shift, convective amplification, spherical spreading, atmospheric absorption, and ground impedance. A typical result with the aircraft flying at an altitude of 300 feet, a velocity of 108 knots, and with the source radiating at 4 kHz is illustrated. The static and the flight-adjusted data agree within ±2 dB for emission angles from 20° to 100°. This good agreement establishes the adjustment procedures and suggests that installation effects will not be significant for the high-frequency-turbofan engine tones.

The second result was obtained from an instrumented engine during tests at simulated forward speed in the Ames 40 × 80 wind tunnel. Analyses of unsteady pressure data from transducers mounted on the fan blades indicate that fan-rotor/turbulence interaction is the dominant noise source at static conditions, but reduces in intensity as flight velocity increases. Above about 20 knots, another noise source, the fan-rotor/potential flow field interaction, becomes dominant. This latter source was found to be relatively insensitive to further increase in forward velocity.

John S. Preisser, 3841 (505-32-03)

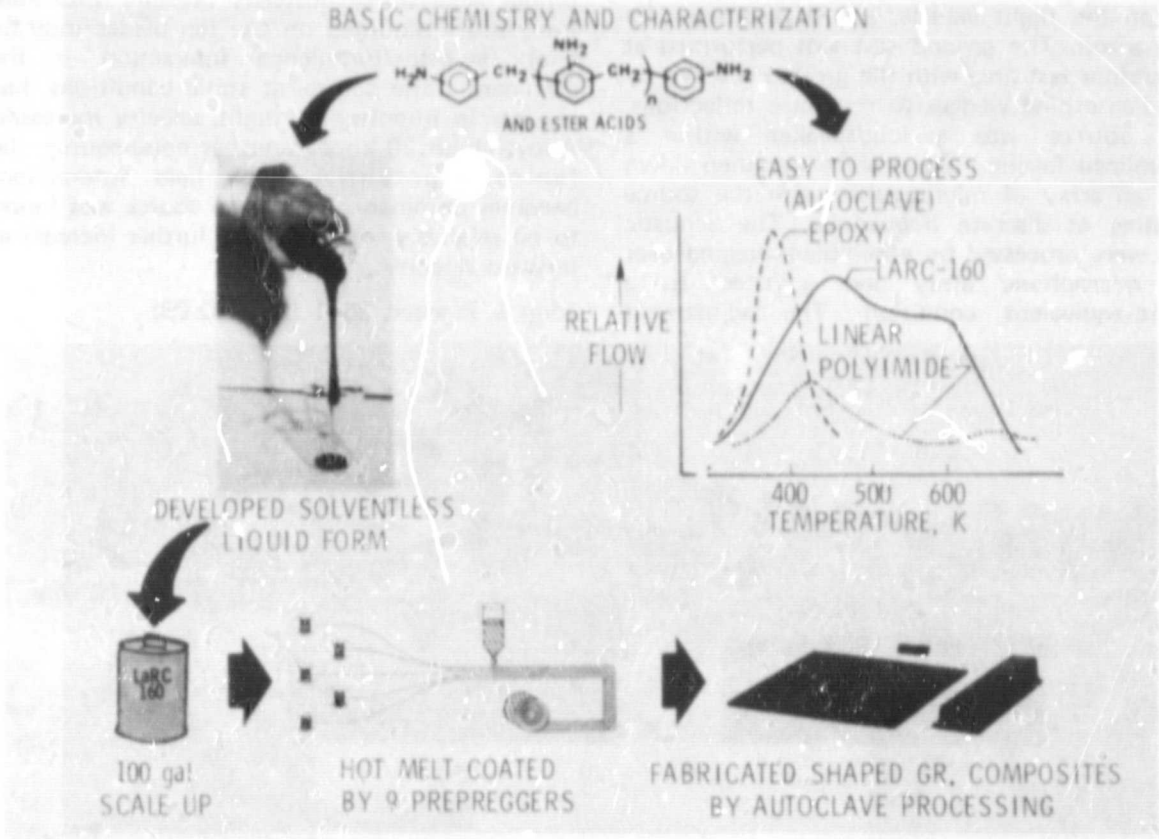


Comparison of static and flight directivity patterns from an acoustic source

LaRC-160 Polyimide Matrix Resin

LaRC-160 polyimide matrix resin, a material discovered at Langley and awarded Industrial Research Magazine's prestigious IR-100 award in September 1979, has received wide acceptance in the aerospace industry's research and technology programs on advanced performance composites. This unique, low cost resin system has a combination of desirable physical properties, such as excellent low pressure flow characteristics, which make it an attractive candidate for versatile processing into strong, low void composites. Excellent retention of composite properties results after exposures in excess of 500 hours at 560 – 575 K. The resin is now being marketed and the carbon fiber prepreg material made from LaRC-160 is also commercially available from five companies in the United States. Several foreign companies have expressed an interest in licensing patent rights from NASA. In addition to several NASA composite development programs based on LaRC-160, a number of Department of Defense and private aerospace firms have selected LaRC-160 as the matrix resin of choice for use in developing composite components for missiles, engines, and filament-wound vessels. In addition, Technology Utilization has handled over 700 requests for information on this promising material.

T. L. St. Clair, 3041 (505-33-33)



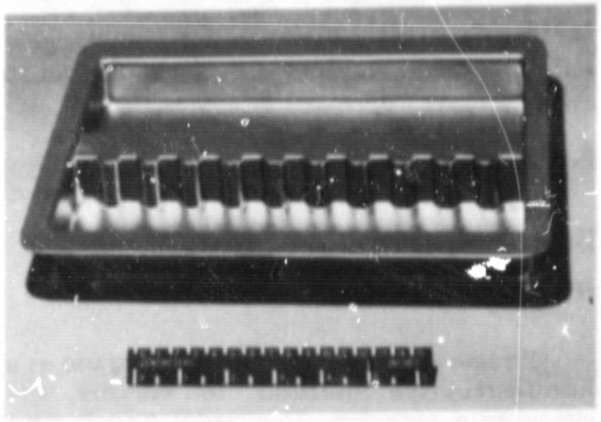
LaRC-160 polyimide matrix resin

Superplastically Formed and Weldbrazed Compression Panels

Two relatively new Ti processing procedures, superplastic forming and weldbrazing (SPF/WB), have been successfully combined to fabricate titanium members which should exhibit improved structural efficiency and durability compared to titanium structures fabricated by conventional means. The combined use of SPF/WB offers processing advantages by

exploiting the use of superplastic forming to fabricate stiffener configurations that cannot be fabricated using conventional processes and the use of weldbrazing to produce skin-stiffened structures having a ductile aluminum braze joint for improved durability and resistance to crack propagation compared to titanium structures having integral joints. Beaded web and conventional hat stiffener configurations have been superplastically formed and attached to Ti-6Al-4V titanium alloy skins by weldbrazing. Preliminary studies show that approximately 30 minutes at 1200 K are required to superplastically form the stiffeners and approximately 5 minutes at 950 K are required for weldbrazing. Similar specimens fabricated by SPF/DB (superplastic forming and diffusion bonding) would require processing at a temperature of 1200 K for a period of approximately 4 hours. The shorter time and lower temperatures required for SPF/WB should produce a much smaller degrading effect on material properties than is found for SPF/DB.

T. T. Bales, 3405 (505-33-33)

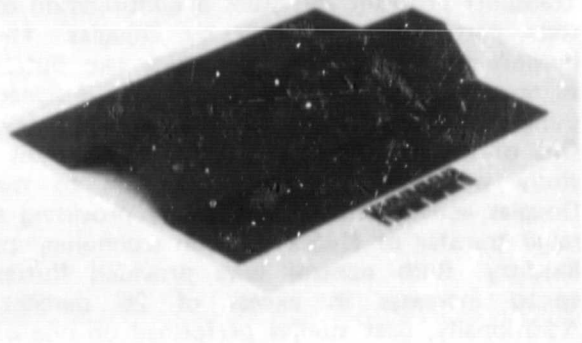


Superplastically formed and weldbrazed titanium compression panel

Hot Forming Graphite/Polyimide

A simple fabrication procedure which offers several advantages compared to conventional autoclave curing has been used to fabricate graphite/polyimide composite elements. Both Celion/LaRC-160 and Celion/PMR-15 hat-shaped stiffeners have been built. Briefly, the procedure is: (1) the appropriate number of prepreg plies is assembled into the required orientation, (2) the resulting laminate is B-staged under vacuum, (3) the laminate is placed between 519 K preheated matched metal dies, (4) contact pressure is applied and maintained for 10 minutes, (5) 2.07 MPa pressure is applied and the temperature is increased at 3 K/min until 603 K is achieved, and (6) the part is maintained at 603 K for 30 minutes and then cooled at 3 K/min under pressure until the temperature is reduced to 366 K. Free standing postcure in an air-circulating oven is used to increase the glass transition temperature of the composite element if required. Several advantages are apparent from results obtained to date. Once the B-staging operation has been completed, the composite can be stored at room temperature for at least 6 months without degrading. Ten replicas of three different batches of composite material have been successfully fabricated and demonstrate the process reliability. Compared to autoclave curing, the hot forming process requires less energy.

R. M. Baucom, 3940 (505-33-33)



Hot formed graphite/polyimide hat-shaped stiffener

Decoupler Pylon for Suppression of Wing/Store Flutter

To satisfy multimission requirements, modern fighter aircraft must carry many types and combinations of external wing-mounted stores. The carriage of such stores can reduce the flutter speed and thereby degrade the operational and mission effectiveness of combat aircraft. Because of the importance of flutter avoidance, considerable research has been conducted to develop and assess the capabilities of both active and passive flutter suppression concepts. An effective yet simple passive flutter suppression concept has been demonstrated in

wind-tunnel model investigations of two advanced fighter configurations – the F-16 and YF-17. These research studies indicate that the performance of the decoupler pylon system compared favorably with that of active flutter suppression systems. It not only provides substantial increase in flutter speed but also reduces the sensitivity of flutter to changes in store inertia and center-of-gravity location. Based on these promising results a program leading to a flight demonstration of the decoupler pylon on an F-16 has been initiated.

F. W. Cazier, 2661 (505-33-53)

Active Control Increases Transport Flutter Speed

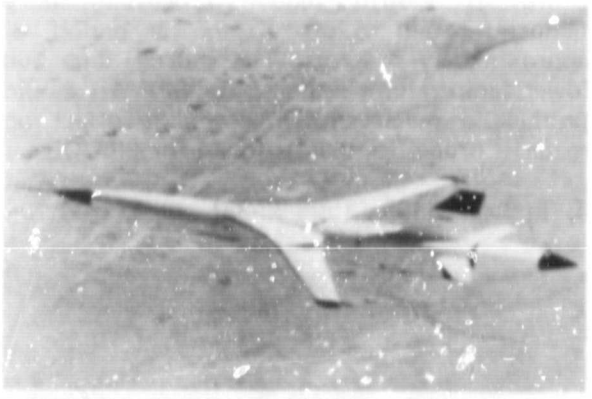
NASA-developed control laws for a wind-tunnel model of a DC-10 derivative wing were tested in cooperation with the McDonnell-Douglas Company. These cooperative studies were funded under the Energy Efficient Transport program and were a continuation of tests performed previously by Douglas. The purpose of these tests was to study two flutter suppression control laws that were designed using new methods developed at NASA Langley. One of the main objectives of this cooperative study was to make a contribution to the Douglas active control program by providing a rapid transfer of NASA research technology to industry. Both control laws provided flutter speed increases in excess of 25 percent. Additionally, gust studies performed on one of the control laws indicated significant reductions in gust loads when tested in turbulence.

J. R. Newsom, 3323 (505-33-63)

New Flight Flutter Test Technique

The acquisition of flight flutter data in the flutter region is especially invaluable for validation of synthesis and analysis techniques for flutter suppression systems. Nearly all flight flutter tests are aimed at verifying flutter clearance within the flight envelope of a particular aircraft and the accuracy of the predictions is not determined. A technique has been developed and demonstrated for acquiring the needed data from high-risk type tests by using a low-cost unmanned remotely piloted research vehicle. From utilization of modern data acquisition and transmission methods with new computation technology, near real-time assessments have been made of wing response to excitation by sine wave frequency sweeps of short duration. The flutter boundary of a research wing was established in a flight made in March 1980. The accompanying figure is a photograph of the test vehicle and research wing in flight. The realistic flight environment allows accurate evaluation of system performance. While some refinements are still needed in the test technique, successful demonstration has been accomplished.

N. N. Murrow, 3527 (505-33-53)



Flutter test vehicle

First Observation of Ultrasonically Induced Dilation

Ultrasonics has steadily been gaining use as a nondestructive method to evaluate and characterize materials. Theoretical models have been extensively used to help understand experimental observations. One such model, which deals with nonlinear ultrasonic theory for solids, predicts a dilation of the solid in the presence of a high frequency ultrasonic wave. Although this model has been in existence for about 20 years, the dilation up to the present has never been observed. Recently, the ultrasonic dilation has been experimentally observed for the first time. This exciting observation opens another area of experimental nonlinear acoustics. It provides a new tool for the nondestructive characterization of materials by providing information on higher order elastic constants.

The experiment was performed with a single crystal germanium sample. The dilation was

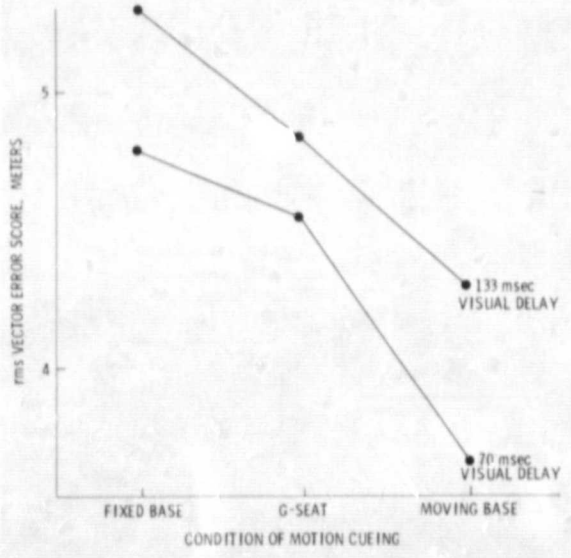
observed by placing a cylindrical sample in a configuration where one of its ends was half of a parallel plate capacitor. A small change in the length of the sample changes the capacitor gap spacing and therefore changes its capacitance. The change in capacitance is then measured. A transducer mounted on the other end of the sample was excited to induce an ultrasonic pulse in the sample. The change in the capacitance during the ultrasonic pulse was then measured.

The theory predicts that the amplitude of the dilation will be proportional to the square of the amplitude and the square of the frequency of the ultrasonic wave. Therefore, the signal amplitude was measured as a function of the frequency and amplitude of the ultrasonic wave. The signal was found to have the correct functional dependence, thus confirming the ultrasonic induced dilation.

John Cantrell, Jr., 3418 (505-33-43)

Motion/G-Seat Study in Helicopter Trainer

A simulation experiment to collect data useful for the specification of helicopter training devices for the LAMPS MK III helicopter was completed by Langley personnel. The experiment examined the effects of destroyer ship movement, visual system delay, and fixed base/moving base/G-seat conditions on hover performance across 14 Navy pilots.



Vector error score averaged over pilots and ship movement conditions

In general, better performance was associated with the shorter delay and the platform motion condition. G-seat performance was significantly better than fixed base performance, approaching that of the platform condition.

R. V. Parrish, 3874 (505-35-33)

Tone Burst Spectroscopy Measures Fatigue Damage in Composites

The increased use of composite materials in the aircraft energy efficiency research programs has placed demands on the field of nondestructive evaluation (NDE). An important aspect of NDE continues to be the development of quantitative rather than qualitative techniques. A significant advance has occurred at Langley which places the art of NDE much closer to the physics of materials. The advance involves phase insensitive tone burst spectroscopy (TBS) which combines Langley's IR-100 award winning phase insensitive transducer with a novel acoustics spectrometer system. The combination is capable of quantitative spectroscopy and is finding appropriate application to studies of composite materials. In the past, accurate spectroscopy in inhomogeneous materials was complicated, if not impossible, due to transducer phase cancellation and system pulse shape artifacts. In many instances complex deconvolution was necessary to eliminate system responses and phase cancellation and nonlinear transducer drives were nearly impossible to eliminate. The new TBS system uses a tracking generator spectrometer instrument with a gating logic device developed at Langley. The results of the technique are striking — no electronic system deconvolution, no transducer phase cancellation artifacts, no nonlinear transducer drive voltages, and no critical propagation geometry setup problems. Using the TBS technique, early fatigue damage in composites has been observed and quantitatively analyzed which demonstrates the detection of significant changes in material attenuation and attenuation gradient. It is thus evident that the TBS technique provides a significant advance in nondestructive estimation of fatigue damage in composite materials.

John Cantrell, Jr., 3418 (505-33-43)

Decoupled Controls for Improved Safety in Wind Shear

Wind shear occurring during approach and landing has been a significant factor in several airplane accidents that have occurred during the past few years. A classic example was the Eastern 66 crash at Kennedy in 1975.

A decoupled longitudinal control system has been developed to improve the pilot's ability to make safe landings in severe wind shear. The decoupled control system uses constant gains to implement changes in thrust, elevator position, and symmetric spoilers to provide independent or decoupled control of flight-path angle, pitch angle, and forward velocity.

The decoupled control system has been evaluated using a fixed-base simulation of the NASA Terminal Configured Vehicle (TCV). Three research pilots were used as subjects and the simulation modeled a typical twin-engine jet transport. Both the conventional control system and the advanced TCV control system crashed approximately half of the time in simulated Kennedy wind shears because they pitched to high angles of attack and stalled. However, when the decoupled control system was used, the airplane did not stall and the pilots were always able to complete safe landings.

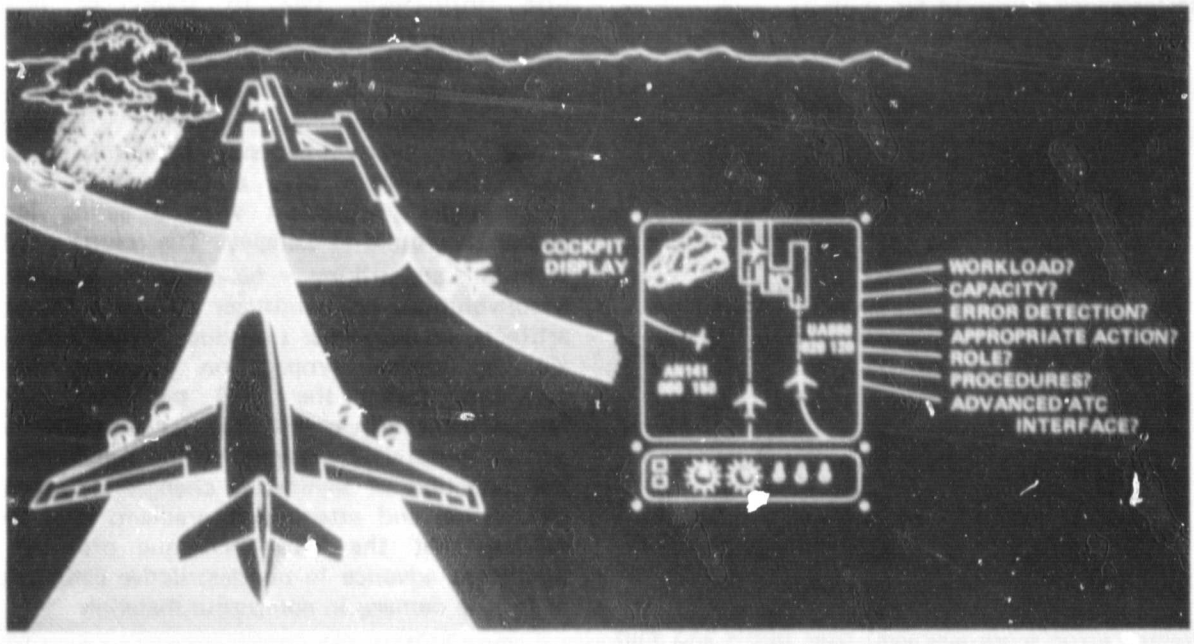
These results indicate a significant potential for improved safety in the terminal area environment with a decoupled control system that can be incorporated in any airplane that uses servo driven actuators.

G. K. Miller, 4591 (505-34-33)

Cockpit Display of Traffic Information

NASA and the FAA are engaged in a joint program aimed at investigating the potential benefits of providing the pilot with a display which shows the positions of surrounding traffic. The technical feasibility of such a concept, generally referred to as the "Cockpit Display of Traffic Information," has been made possible by the availability of airborne electronic displays and planned upgrading of the air traffic control (ATC) system to provide a two-way data link between aircraft and the ATC system.

Flight tests, representative of an advanced implementation scheme, wherein traffic would be displayed on the electronic horizontal situation indicator were conducted using the Langley TCV B-737 research airplane. The results indicated that the traffic display contributed substantially to the flight cr overall situation awareness and provided amp lead time for detecting and resolving conflicts that were introduced into the traffic scenarios. Furthermore, as a potential benefit for improved



CDTI concept

airway capacity and increased operating efficiency, pilot commentary indicated that the less-than-normal traffic separations that were tested were acceptable and that monitoring the traffic display did not adversely affect performance of their other piloting tasks. This work did, however, highlight the need for additional attention to the problem of display clutter.

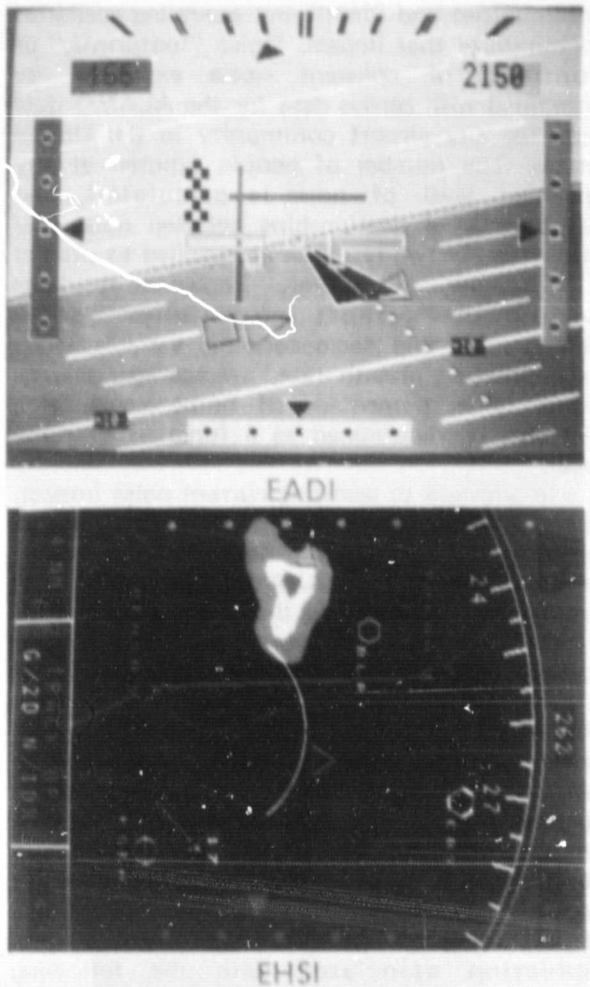
John F. Garren, Jr., 3621 (534-04-13)

Advanced Display Generation Concept

A major element of the Cockpit Avionics R & T base program is research on advanced display generation technology which can provide integrated multimode display information in cockpits of future civil aircraft. The emphasis in the program is the development and evaluation of high-speed faster scan graphic technology which can employ the recent dramatic developments in microcircuit/microprocessor technology and provide attendant advantages of color, shading, and image construction.

A NASA/University/Industry team effort is developing an advanced experimental programmable display generator for laboratory/simulator research. In accomplishing this objective, a contract has been awarded to IKonos Graphics Systems for development of the system. The Research Triangle Institute has been awarded a companion contract for development of applications/systems software. Also, the N.C. State research grant continues to develop advanced display generation algorithms.

The experimental display generator will provide a significant advance in real-time colorgraphic display capability for cockpit simulators. The accompanying photograph shows typical display formats achievable with the new technology. The effort has become the basis for several future advanced flight deck applications programs at Lockheed-Georgia, the Naval Training Equipment Center, and the NASA-Langley Terminal Configured Vehicle Program Simulation Group.



Benchmark display formats

Jack J. Hatfield, 3290 (505-34-23)

LORAN-C/Vermont Flight Experiment

The LORAN-C system is being expanded to provide more coverage and better geometry for most of the Continental United States, Alaska, and the coastal regions. This system expansion, coupled with recent commercial development of relatively low cost LORAN-C aircraft navigation equipment, has generated increased interest in using LORAN-C for area navigation and nonprecision approaches. The impetus to use LORAN-C is greatest in areas such as the state of Vermont, which has sparse VOR coverage, small airports in mountainous terrain, and consequently high approach minimums and limited air accessibility. Seeing economic benefits in increasing air accessibility, the state approached the federal agencies for assistance in evaluating LORAN-C. This led (Fall-78) to formation of a joint program with the state of Vermont, NASA, DOT/TSC, and the FAA. The program goals were (1) define LORAN-C performance in a realistic aircraft control environment for enroute, terminal, and approach route segments, (2) develop a data base to

support Vermont's request for LORAN-C certification and reduction of airport minimums, and (3) investigate long term grid stability in a mountainous region.

Vermont provided the test aircraft and conducted the field operations; DOT/TSC has overall responsibility for coordination, test planning, and certification documentation; the FAA flew independent enroute verification flights. Langley's role was to develop the flight instrumentation containing the LORAN-C navigator, a multilateration position reference system, and a data acquisition system to record at 1 second intervals the reference system and LORAN-C derived position and navigation parameters. Langley also developed a ground-based data system to record long term grid variation. In addition, Langley provided the data reduction and analysis.

The instrumentation was test flown on NASA aircraft at Wallops for verification and then deployed to Vermont. Forty data flights and additional demonstration flights were flown over the year test period currently ending. A typical flight profile shows the planned course and the LORAN-C derived track (navigation using LORAN-C). Test results were excellent and have been disseminated through articles in Aviation Week and Air Progress, conference papers, aviation community and FAA briefings, and certification submittals.

C. D. Lytle, 3631 (505-34-06)

Low Cost G-Cue Substitutes for Flight Simulators

For the past several years, there has been little agreement on the benefits of motion cueing to simulator pilots. Langley has a program to investigate low cost motion cueing technology in an effort to increase the fidelity of piloted simulations. Results to date have shown that Langley designed G-seats and helmet loaders improve the simulator pilot's performance in fixed-base, high performance aircraft simulators. These results are being utilized by industry with more than a half-dozen simulator manufacturers now providing G-seats based on the Langley design and at least three companies now planning to manufacture the helmet loader. Presently at least, 20 of the G-seats have been sold by simulator manufacturers.

Recent experiments have shown G-seat augmentation of platform motion to be beneficial to simulator pilots.

The results of the experiment show that the F-15 subject pilots (performing a tracking task with high pilot workload) exhibit significantly better tracking performance with either G-seat or platform motion versus the no motion cue condition. However, the pilots exhibited even better performance when both G-seats and motion platform cues are present.

B. R. Ashworth, 2344 (505-35-33)

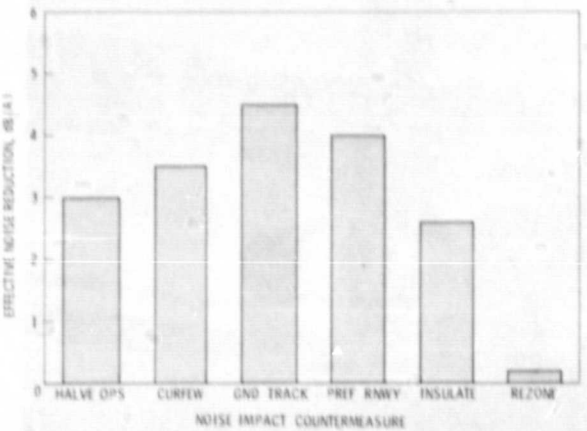
Method for Airport Community Noise Impact Assessment

The aircraft-noise levels and annoyance model (ALAMO) is a computerized method for predicting the impact of aircraft noise on airport communities and identifying operating scenarios to minimize that impact. Noise "footprints," or contours, of constant noise exposure are combined with census data for the ALAMO data base for any airport community in the United States. The number of people exposed at any specified level of noise is calculated, and psychophysical relationships between noise and human subjective response are applied to predict the number of severely impacted residents within the airport community. Various demographic and socioeconomic variables such as population growth rate, average age, average home value, percentage of homeowners, etc., can also be determined as a function of noise level.

In addition to assessing current noise impact, the ALAMO can be used to define airport operating scenarios to minimize community noise impact. The ALAMO will determine ground tracks overflying the smallest number of people, determine the takeoff profile, or specify runway use rates that minimize noise impact at a particular airport. It can be used to evaluate the relative effectiveness of these operational noise control measures when compared to land-use and aircraft noise control approaches such as quieter engines, rezoning, and building insulation. As an illustration, the figure summarizes a noise control effectiveness study recently conducted for a major midwestern airport using the ALAMO. The effective noise reduction associated with the following approaches to community noise control are

compared: (1) cutting the number of operations in half, (2) imposing a night curfew, (3) flying population-minimal ground tracks, (4) a preferential runway use policy, (5) sound insulation for homes exposed to noise levels greater than 65 decibels on the Day-Night Level (LDN) scale to give an additional 6 decibels of structural noise loss, and (6) rezoning to force relocation of all residents currently exposed to noise levels in excess of 75 decibels on the LDN scale. The most effective countermeasure for this particular airport was flying population-minimal ground tracks.

Richard DeLoach, 3561 (505-35-13)

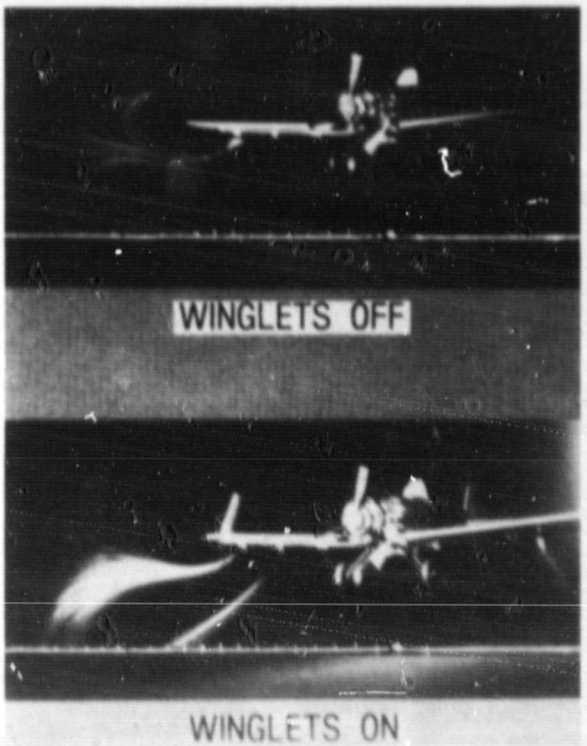


Effective noise reduction for a particular airport

Aerial Applications Technology

Testing conducted with a scale model agricultural airplane in the Langley Vortex Research Facility has demonstrated the effect of winglets on reducing off-target drift of aerially applied chemicals. Winglets mounted on a scale-model Thrush agricultural airplane reduced vortex entrainment of particles released from the wing. This reduced vortex entrainment is estimated to result in a 30-percent reduction in spray drift (with no change in swath width). The figure illustrates with flow visualization the tendency for reduced vortex effect (with winglets on) on trajectories of particles released near the wingtip. Reduced drift of chemicals has significant environmental and economic importance. A 30-percent reduction in spray drift could save the aerial applications industry approximately $15-$20 million annually. Full-scale flight testing is in progress to confirm the small-scale model results.

F. L. Jordan, 2543 (505-41-83)



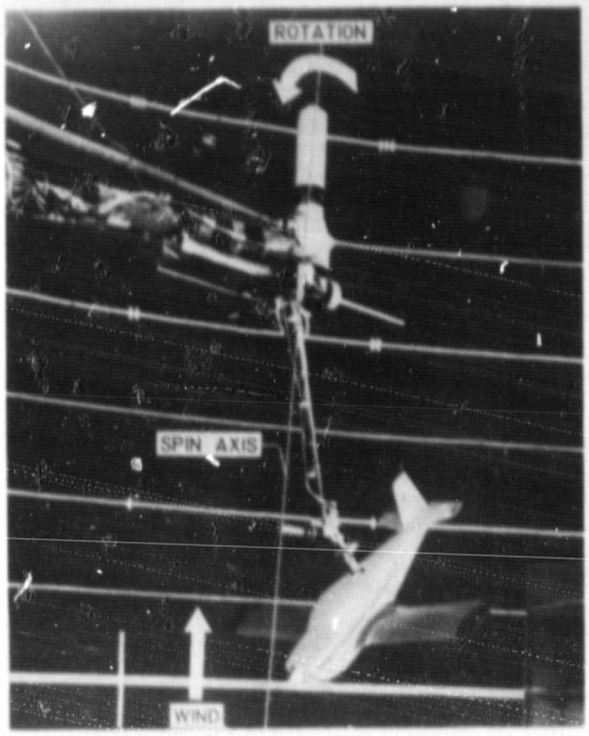
Effect of winglets on particle entrainment

General Aviation Stall/Spin Research

A rotary balance located in the 20-foot spin tunnel at Langley is being used to measure an airplane's aerodynamic characteristics in the rotational flow environment of a spin. Recently, one of the most productive unions of analysis tools has been accomplished by joining rotary-balance techniques with on-line mini-computer analytical methods for prediction of potential spin modes. With this equipment, it is possible to measure aerodynamic forces and moments for a particular model configuration over the range of variables expected in the spin, and then instantaneously employ an on-line mini-computer program (which has been preloaded with equations of motion and airplane mass information) for an immediate prediction of potential spin modes. This on-line analysis capability offers a new dimension in the determination of spin modes, recovery control

effects, airframe component effects, and parameter sensitivity studies. When coordinated with spin tunnel tests, important factors affecting an airplane's spin and recovery characteristics can be defined.

J. R. Chambers, 2184 (505-41-13)



Model on rotary balance

Quieter General Aviation Propeller Demonstrated

Propeller noise from general aviation aircraft is a problem for many communities. Typical propeller noise reduction methods rely on relatively old technology and usually result in a substantial performance penalty. Recently developed technology has been demonstrated to reduce propeller noise without a significant performance penalty. This was accomplished when a new propeller noise prediction methodology developed at the Langley Research Center was transferred to Massachusetts Institute of Technology for use in a study to optimize the noise and performance characteristics of light aircraft propellers.

MIT has completed the project by demonstrating the quiet propeller design on a Cessna 172 aircraft. The quiet propeller has a larger inboard chord, a smaller diameter, and operates about 100 rpm slower than the standard propeller. The flight demonstration was conducted at FAA noise certification conditions, i.e., 300 m flyover at full power. The quiet propeller averaged 4.8 dB(A) quieter than the production propeller over the 36 run test sequence. Performance, as indicated by aircraft rate of climb, was unchanged except at the higher aircraft speeds.

George C. Greene, 2645 (505-41-43)

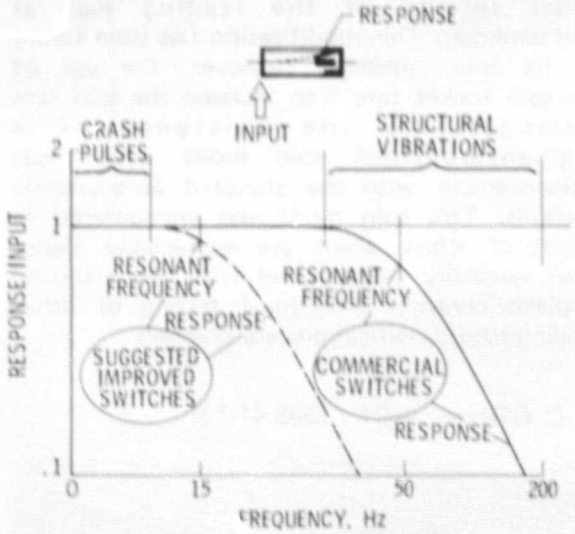
Quiet propeller on a light aircraft

Emergency Locator Transmitter Reliability

General aviation aircraft are required to carry emergency locator transmitters (ELT's) intended to be activated in a crash to expedite the location of downed aircraft by search-and-rescue people. In-service, ELT's have exhibited notoriously poor reliability, severely limiting their effectiveness. Problems in properly activating ELT's have been studied by mounting a sampling of these devices in full-scale crash test aircraft and in a special laboratory test

apparatus which simulates crash pulses. One performance deficiency has been discovered in the vibration sensitivity of ELT inertia switches illustrated schematically at the top of the figure. The solid curve in the figure shows the ratio of response to input as a function of frequency for a typical ELT of current design. Data indicate that resonant frequencies of these switches fall in the range of frequencies of local structural vibrations that exist in general aviation aircraft. The frequency range of crash pulses, on the other hand, is on the lower end of the frequency spectrum as indicated in the figure. The switches, therefore, are often too responsive to local structural vibrations which can trigger unwarranted activations or prevent activations in a crash situation. A suggested improvement involves redesign of the switch to lower the resonant frequency and to change the frequency-response characteristics to that shown by the dashed line in the figure. An experimental switch with such a characteristic has been built and tested and found to possess more desirable performance characteristics.

Huey D. Carden, 3795 (505-41-33)

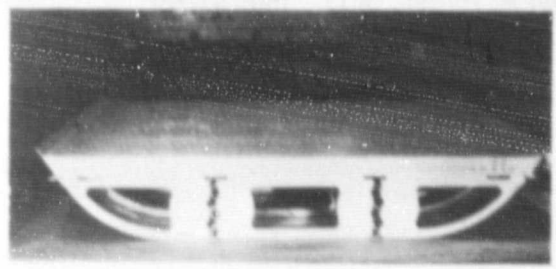


Inertia switch vibration response

Load-Limiting Subfloor Structure

Understanding how to limit loads transmitted to occupants in general aviation aircraft in a crash situation is one aspect of crash dynamics research. One approach is to design the subfloor structure to dissipate kinetic energy by appropriate structural arrangement, astute shaping of geometry of structural elements, or incorporating clever energy dissipating devices. Five load-limiting subfloor structural specimens have been constructed and tested statically. The structural concepts in each of these specimens could be used to replace currently used subfloor structure and consist of a relatively strong floor structure to maintain seat/aircraft integrity undergirded by a crush-type structure which is intended to collapse in a controlled manner. One of the more promising of these modified structural concepts is shown in the figure. Test results for the five new concepts indicate that they perform well in that the upper floor remained intact throughout the loading, and the crush-type structure collapsed at a generally lower load level than would be required to collapse a conventional structure. The crushing load remained relatively uniform in magnitude throughout the loading cycle. Dynamic drop tests for these load-limiting concepts are currently in progress at velocities up to 9 m/s to compare impact performance with conventional subfloor structure.

Huey D. Carden, 3795 (505-41-33)



Modified subfloor structure corrugated beams

Display Enhancement of Instrument Landing System

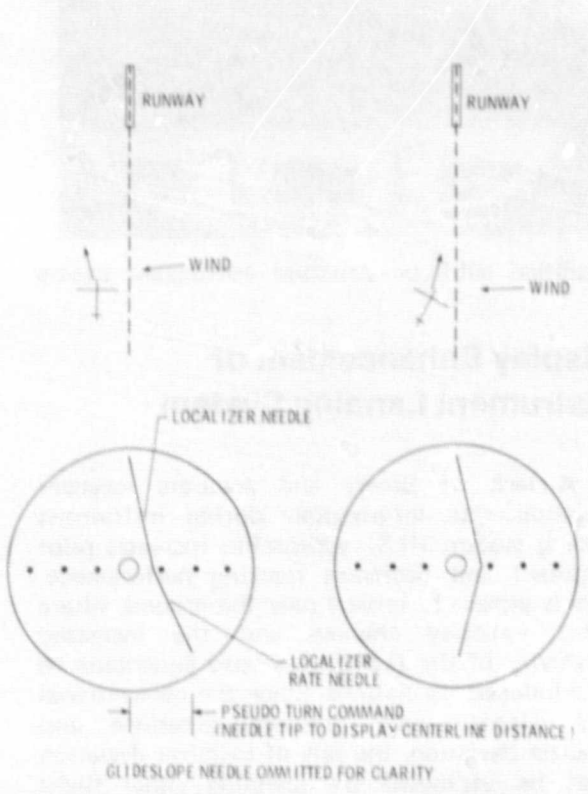
A lack of timely and accurate localizer deviation rate information during instrument landing system (ILS) approaches increases pilot workload and decreases tracking performance. This is especially critical near the ground, where wind velocity changes and the increased sensitivity of the ILS display may contribute to pilot-induced oscillations. Since the conventional ILS display only presents glideslope and localizer deviation, the rate of localizer deviation must be estimated by scanning other flight instruments. The aircraft heading required to maintain zero deviation rate while on the

localizer is found by trial and error and may vary as the aircraft descends into changing winds.

The pseudo command tracking indicator (PCTI) is an enhancement of the conventional ILS display. Localizer deviation rate is presented on the PCTI by a rate needle attached to the end of the localizer needle. The display is configured so as to present raw deviation data, localizer derivation rate, and a pseudo turn command. The turn command is a function of localizer deviation and deviation rate and is indicated by the distance between the lower end of the rate needle and the vertical centerline of the display. The PCTI eliminates the need to find the correct heading by trial and error and permits more rapid corrections for wind changes.

A simulation study was conducted with the PCTI. Eight pilots each flew five approaches with the conventional display and five approaches with the PCTI. The average rms error of localizer tracking using the PCTI was about one-half the error using the conventional display.

David A. Hinton, 3917 (505-41-73)



Pseudo command tracking indicator

Spin Research With a Research Rocket System

A spin recovery system using hydrogen peroxide rockets mounted on the wing tips of a light airplane has been developed and is being used in a stall/spin research program. The system has the capability of providing repeated recoveries from fully developed spins during a single flight and, thus, facilitates the stall/spin research testing of experimental modifications which can be made to the test bed aircraft. A major advantage of the rocket system is its capability to increase the spin rate, as well as to retard it. In the pro-spin mode, the system has the capability to generate spins at very high angles of attack and can, therefore, demonstrate configuration effects on the stall/spin characteristics and can readily expose all possible spin modes of the airplane.

Presently the rocket system is being used to study the effects of wing leading-edge modifications on the spin and spin recovery characteristics of the test airplane. The leading-edge configuration presently being tested is a leading-edge gap obtained by removing a short section of the leading edge at mid-semispan. This modification has been found to be spin resistant. However, the use of pro-spin rocket forces to increase the spin rate demonstrated the existence of a high-angle-of-attack spin mode which was unrecoverable with the standard aerodynamic controls. This spin mode was encountered at angles of attack which are appreciably higher than normally encountered with the standard airplane controls. Additional testing of other leading-edge modifications are planned.

T. C. O'Bryan, 4591 (505-41-13)

Research aircraft

Helicopter Vibration Analysis

Advisory committees have called for a NASA attack on problems in analysis of helicopter vibrations. Particularly cited have been difficulties in predicting vibrations of the airframe structural system and in accounting for airframe participation in overall vehicle vibrations. A good deal of progress has been made in recent years on vibrations analysis methods for the rotor system and the airframe system considered separately. It has been widely recognized that an opportunity exists to make a significant advance in the capability of industry to deal analytically with vibrations through effective integration of these now existing methods for the rotor and the airframe.

A Langley team has developed analysis and computation procedures which serve as a complete basis for planning and establishing such an integrated capability. The airframe is represented by a general finite-element model such as embodied in the NASTRAN computer code, which has become the standard structural analysis tool in the U.S. helicopter industry. The rotor is represented by general linear differential equations with periodic coefficients which can be specialized to represent any rotor undergoing small vibrations with reference to an arbitrary trim state. Coupling of the rotor to the airframe is implemented through general equations which may be specialized to represent any interface arrangement likely to be encountered. The coupled equations of motion are solved for steady flight vibrations using the "harmonic balance" method. In the solution process the airframe participation is represented by forced responses of the airframe at a finite number of harmonics of the rotor rotation frequency.

All mathematical steps necessary to meet the objective are developed as explicit computational procedures ready for computer coding. These results are a basis for significant improvement in reliability and speed of practical analysis of helicopter vibrations by industry structures departments.

R. G. Kvaternik, 2661 (505-42-13)

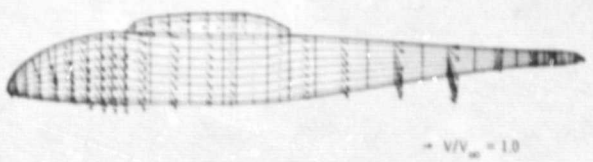
Rotor Wake Effects on Helicopter Fuselages

The downwash induced by a rotor on a helicopter fuselage and its empennage is an important effect in determining the overall vehicle performance. This effect is generally most evident in hover and low-speed flight as fuselage downloads and adverse torque loads. As a result, there is a need to predict the flow-field conditions around the vehicle.

Several analytic methods which use source/sink or doublet panels to model rather complex vehicle components have been developed. In addition, several analytic methods which use either strip theory, vortex ring, lifting line, or lifting surface theories have been developed to model and analyze free wakes from rotors. The next step in the evolution of analytic methods to solve the total problem of rotor/fuselage interference is the validation of the present method with experimental data and the coupling of the two types of methods.

Even though the dynamic nature of the wake on the aerodynamics of the rotorcraft is important, there are many problems which can be analyzed using a mean downwash field. Work has been done at the Langley Research Center by Army Structures Laboratory personnel to combine the Heyson and Castles modeling method for a rotor wake using a series of vortex rings with the Douglas-Neumann three-dimensional, inviscid potential-flow method for the fuselage. To evaluate results from this hybrid method, pressure data were obtained on helicopter model with a 3-meter diameter rotor. These tests were conducted in the Langley V/STOL tunnel. Results from the wind-tunnel test and the computer program agree very well. The figure shows the computed flow patterns on the model fuselage.

Carl E. Freeman, 3611 (505-42-13)



Calculated fuselage surface flow characteristics; $C_T = 0.0066$, $\mu = 0.05$

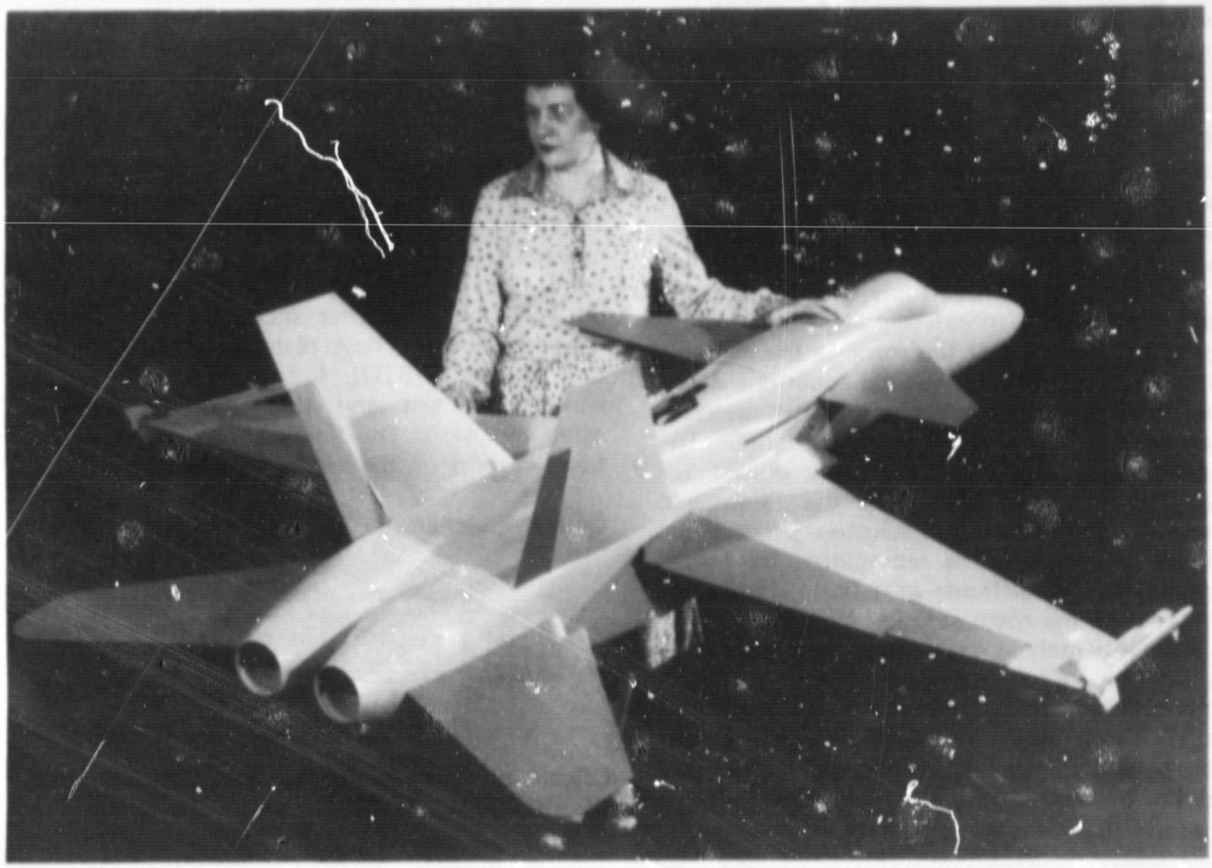
Military Stall/Spin Research

Military stall/spin research conducted at Langley is dedicated to providing the U.S. with the technology needed to develop high-performance military aircraft having satisfactory stall/spin characteristics which enhance, rather than limit, tactical effectiveness. During the past year, accomplishments have

included support of the F-18 airplane development, demonstration of high angle-of-attack control technology with F-14 flight tests, investigation of high angle-of-attack flow phenomena causing undesirable wing rock on highly swept wing designs, and study of advanced fighter designs.

Langley tests and analysis successfully predicted the stall/spin characteristics of the F-18 and identified configuration changes to provide improvements. Continuing F-14 high angle-of-attack flight tests have further demonstrated that current high angle-of-attack automatic control technology can provide large improvements in fighter stall/spin characteristics when properly used and that current piloted simulation technology, such as used on the Langley Differential Maneuvering Simulator, can reliably predict important stall/spin dynamics. Wind-tunnel studies of the stall-flow phenomena causing the wing-rock motion (limit cycle roll oscillation) observed on aircraft having highly swept wings have provided a fundamental understanding of the vortex-flow phenomena producing these motions. Other wind-tunnel studies of the stall/spin characteristics of several advanced airplane concepts, incorporating such features as the arrow wing for supersonic cruise or canards for improved maneuverability, have identified airframe and control system features which will provide improved stall/spin characteristics.

William P. Gilbert, 2184 (505-43-23)



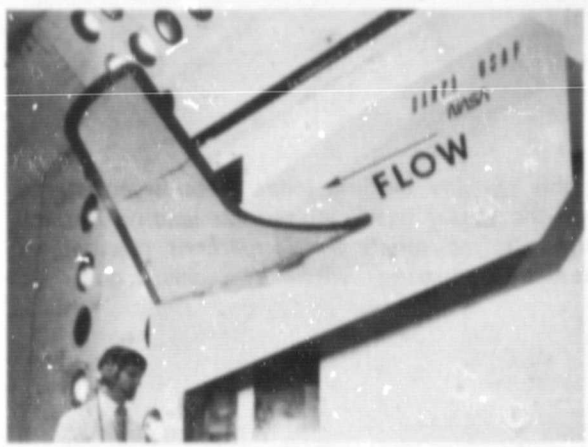
Advanced fighter design

Divergence of Forward-Swept Wings

There is evidence that forward-swept wings may offer aerodynamic advantages over aft-swept wings. However, forward-swept wings must be made much stiffer than aft-swept wings to avoid divergence – a static aeroelastic instability that can quickly destroy the wing. For metal wings this usually results in a prohibitively heavy structure. Now, however,

composite-material structural technology offers a potential solution to the divergence problem by arranging (aeroelastically tailoring) the lamina to reduce the wash-in that is inherently characteristic of forward-swept wings. To verify analytical predictions of the divergence characteristics of forward-swept wings constructed of composite material, wind-tunnel model studies were made in the Langley transonic dynamics tunnel. These tests were conducted in cooperation with the Air Force and the Defense Advanced Research Projects Agency (DARPA), and used two dynamically scaled aeroelastic models of proposed flight demonstrator airplanes. The wind-tunnel test results verified the analytical predictions that high divergence speeds can be obtained by aeroelastically tailoring forward-swept wings with composite material.

R. H. Ricketts, 2661 (505-43-33)



Aeroelastically tailored wing

Aircraft Storm Hazards

The Langley Storm Hazards Program is being carried out to improve the knowledge of severe convective storms as they affect aircraft design and operation. Flight tests in the vicinity of and into such storms were conducted during the 1980 thunderstorm season using a NASA-owned F-106B aircraft. A total of 20 storm flights were made; 9 in Oklahoma in conjunction with ground-based Doppler radar measurements by the National Severe Storms Laboratory of NOAA, and 11 in Virginia in conjunction with ground-based storm measurements by NASA Wallops Flight Center. A total of 68 thunderstorm penetrations were made and the aircraft sustained 10 direct lightning strikes.

During the thunderstorm penetrations, measurements of electromagnetic properties of the lightning which struck the aircraft were made. Other onboard instrumentation systems recorded lightning X-ray emissions, concentrations of nitrous oxide, the optical properties of lightning, and the turbulence environment. A preliminary review of the data shows possible correlations between several of the experiments. Further flight tests will be made in 1982 and 1983.

Bruce D. Fisher, 3274 (505-44-13)

Aircraft Lightning Strike Tests

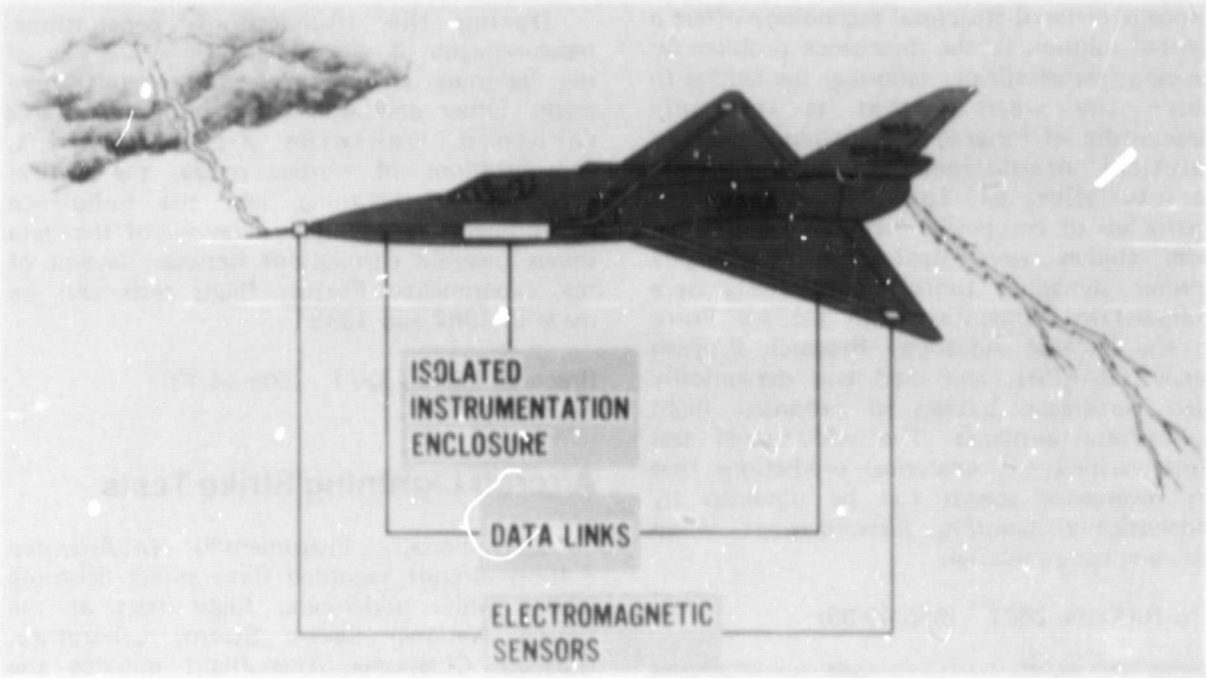
The specially instrumented NASA-owned F-106B aircraft recorded three direct lightning strikes while undergoing flight tests at the NOAA National Severe Storms Laboratory, Norman, Oklahoma. This flight initiates the gathering of data for characterizing lightning-generated electromagnetic environment to be used to guide designs of future digital avionic systems onboard composite (nonmetallic) structured aircraft.

The instrumentation concept shown in the figure consists of a number of sensors mounted on the noseboom, the fuselage, the wing, and the tail which detect the electromagnetic fields during the lightning strike process and a recording system specially shielded and isolated from the lightning strike phenomenon located in the missile bay of the F-106B. The recording instrumentation includes a wideband (6 MHz) video recorder for overall lightning strike phenomenon and a transient waveform recorder modified to capture 1.3 milliseconds of data at a 10-nanosecond resolution. The sensors were derived from designs developed for nuclear electromagnetic pulse measurements.

The initial data analysis indicates the direct lightning strikes had an unexpectedly more active electric field compared to the magnetic field and the electric field's rate of change was significant on a submicrosecond scale.

Flights are continuing with the present instrumentation in an attempt to gather statistically significant strike-characteristic data. Meanwhile, new expanded capability data recording instrumentation is being developed to allow more complete characterization of the lightning-generated electromagnetic environment.

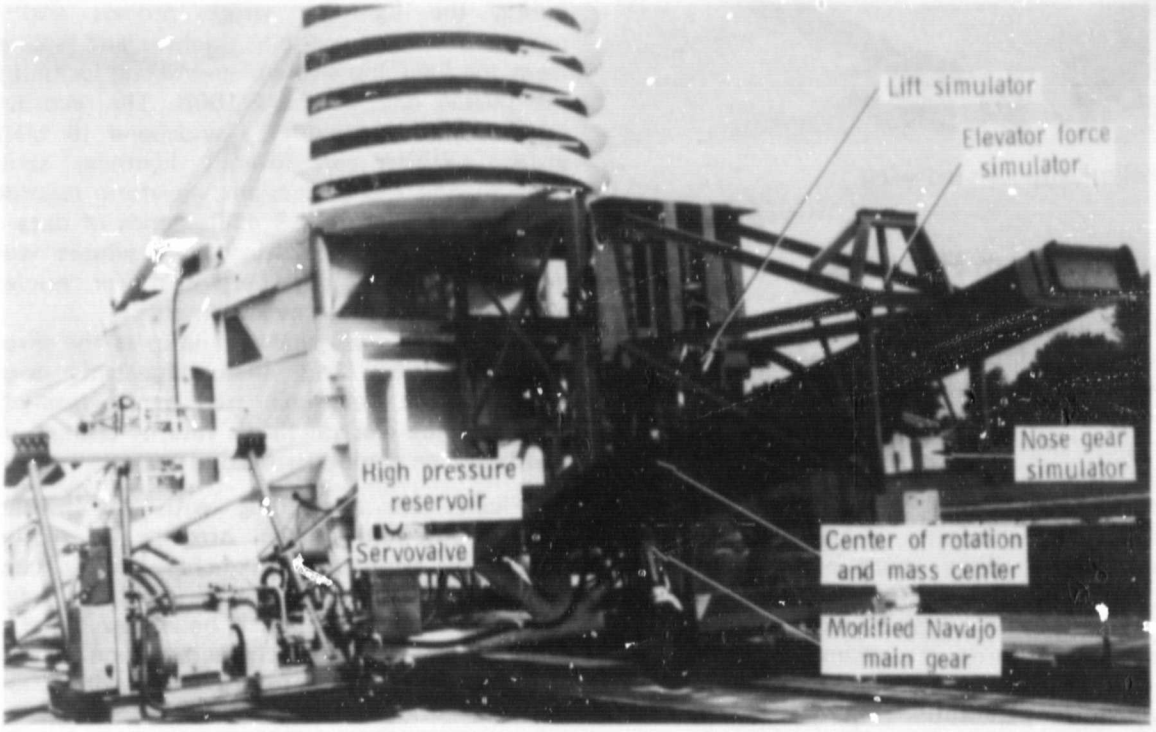
Billy L. Dove, 3681 (505-44-13)



Lightning research instrumentation

Active Control Landing Gear

Experimental data have been obtained from simulated landing tests of a light-aircraft main landing gear equipped with an active load-control system. Results of tests conducted at the Langley landing loads track demonstrate that the active gear can reduce landing impact forces by as much as 19 percent relative to forces occurring with a passive gear at



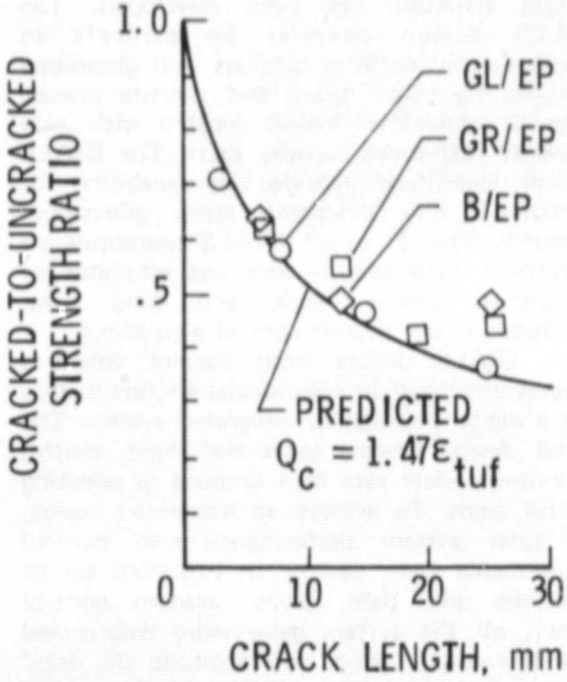
Active control landing gear test apparatus

touchdown sink rates up to 1.5 m/sec during an 80-knot landing (a typical landing speed for light aircraft). The active gear also reduced forces imposed on the test rig by 30 to 70 percent during subsequent rollout over long-wavelength runway unevenness. The test results confirm analytical predictions and illustrate that the active gear has potential for reducing ground loads applied to the airplane during all phases of ground operations. A joint Air Force/Langley study is in progress to examine application of the active gear concept to tactical aircraft operating on hastily repaired, bomb-damaged runways.

J. R. McGehee, 2796 (505-44-33)

Fracture Characteristics of Composite Materials

Composite materials can be made from myriad combinations of fibers, matrices, thicknesses, and fiber orientations. To characterize the resistance to fracture of so many configurations, especially with the variability added by considering discontinuities (such as fastener holes) and damage (from dropped tools), requires an inordinately large number of tests. Recent research at Langley has shown that the fracture strength of laminates can be characterized by a single toughness parameter, Q_c. The parameter is independent of stacking sequence, is easily determined from a few simple tension tests, and is linearly related to the tensile ultimate failure strain of the fibers used in the composite (see the equation in the figure). The figure illustrates that the predicted and measured strengths of damaged laminates agree very well throughout the crack length range of the tests. The materials illustrated are fibers of glass, graphite, and boron, each in an epoxy matrix (Gl/Ep, Gr/Ep, and B/Ep, respectively). The analysis also applies to aluminum matrix materials.



Predicted toughness and strength of damaged composites

C. C. Poe, Jr., 2338 (533-01-13)

Thermal Acoustic Shield for Noise Reduction

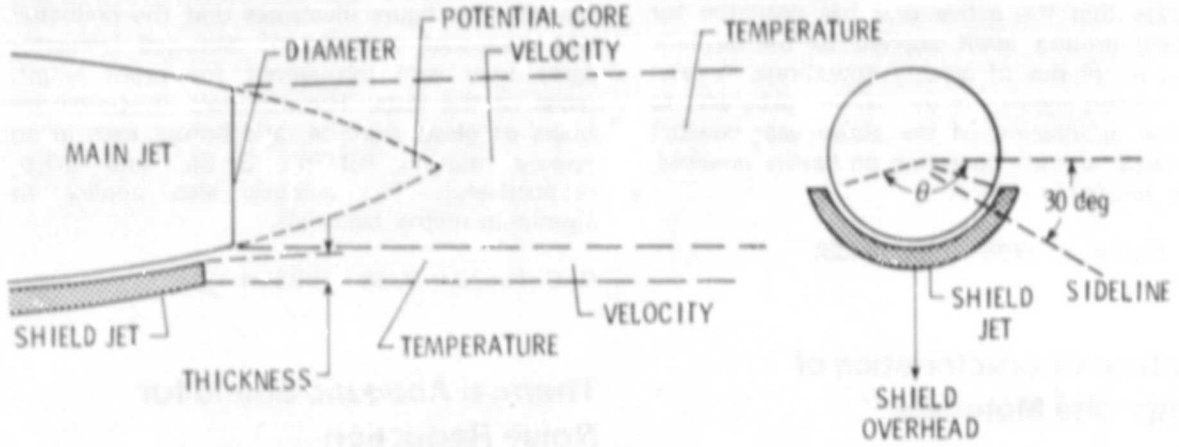
Recent model tests and supersonic cruise engine studies conducted by the Boeing and General Electric Companies have revealed a promising concept for reducing airplane noise at takeoff. The use of a relatively low velocity, high temperature stream between the engine exhaust and the observer on the ground, as shown in the figure, has been demonstrated to be an effective means of reducing the noise perceived by the observer. One of the limitations of the coannular benefit as a single noise reduction concept is the spectrum shift to higher frequencies, which is the basic part of the noise reduction. However, at high velocity levels, the increasing of high frequency levels results in a corresponding increase in the peak overall sound pressure levels. Mechanical suppressors show similar effects and limitations. However, the thermal acoustic shield has the characteristic of strongly reducing high frequency noise while having very little effect on low frequency noise. Preliminary data indicate that, for an SST airplane with GE21/J11-B19 engines, the noise benefits due to the shield could be approximately 5 EPNdB.

In order to determine the practical merits of this concept for AST/VCE application, Boeing and General Electric under NASA contract conducted a study on the mechanical design feasibility (specifically for the GE21/J11-B19 engine) and the effect of the shield on airplane performance. Results show that: (1) the mechanical design is feasible, (2) the weight of the system would be approximately 325 kg

resulting in a range decrease of 160 km on a 6800-km flight, and (3) the thermal acoustic shield is compatible with airplane noise abatement modes.

Current plans are to acquire model scale acoustic data at forward speeds and hopefully to conduct proof-of-concept tests on a large scale engine.

John K. Molloy, 4576 (533-01-43)



Thermal acoustic shield

Fault-Tolerant Computer Designs

Two fault-tolerant computer designs – computers that remain operational in the presence of multiple failures – will be candidates for the heart of all digital avionics on commercial airplanes of the 1990's.

Engineering models of the Software Implemented Fault Tolerance (SIFT) by SRI International/Bendix and the Fault-Tolerant Multiprocessor (FTMP) by Charles Stark Draper Laboratory/Collins are presently being tested and evaluated by the developers. These two computer architectures differ basically in the method of handling faults; the SIFT relying mainly on software algorithms for fault detection and recovery, while the FTMP relies on hardware implementation. The computers have a probability of failure design goal equal to 10^{-9}, and can sustain two major failures.

Normal operation of the computers is being evaluated in preparation for injection tests to include verification of the instruction set, the internal and external bus communications, and behavior of the executive/operating system software.

Billy L. Dove, 3681 (534-02-13)

A Digital Integrated Automatic Landing System

A Digital Integrated Automatic Landing System (DIALS) has been developed. The DIALS design permits an aircraft to simultaneously perform localizer and glideslope captures, fly short finals, and execute precise flares to touchdown points located with easy access to high-speed runway exits. The DIALS control algorithms provide the capability for capturing and tracking steep glideslopes selectable from 3^{o} to 6^{o}. DIALS operations are performed automatically and use estimates of turbulence, steady winds, and wind shear conditions in the aircraft control algorithms.

A DIALS differs from current autoland systems employed in commercial aircraft in that it is a digitally designed, integrated system. The digital design process takes the flight control computer update rate into account in selecting control gains. To achieve an integrated design, the total system performance and control requirements were defined in a unified set of equations and then, using modern control theory, all the system gains were determined simultaneously, taking into account the total effects of multiple control commands on the various modes of aircraft motion. In current

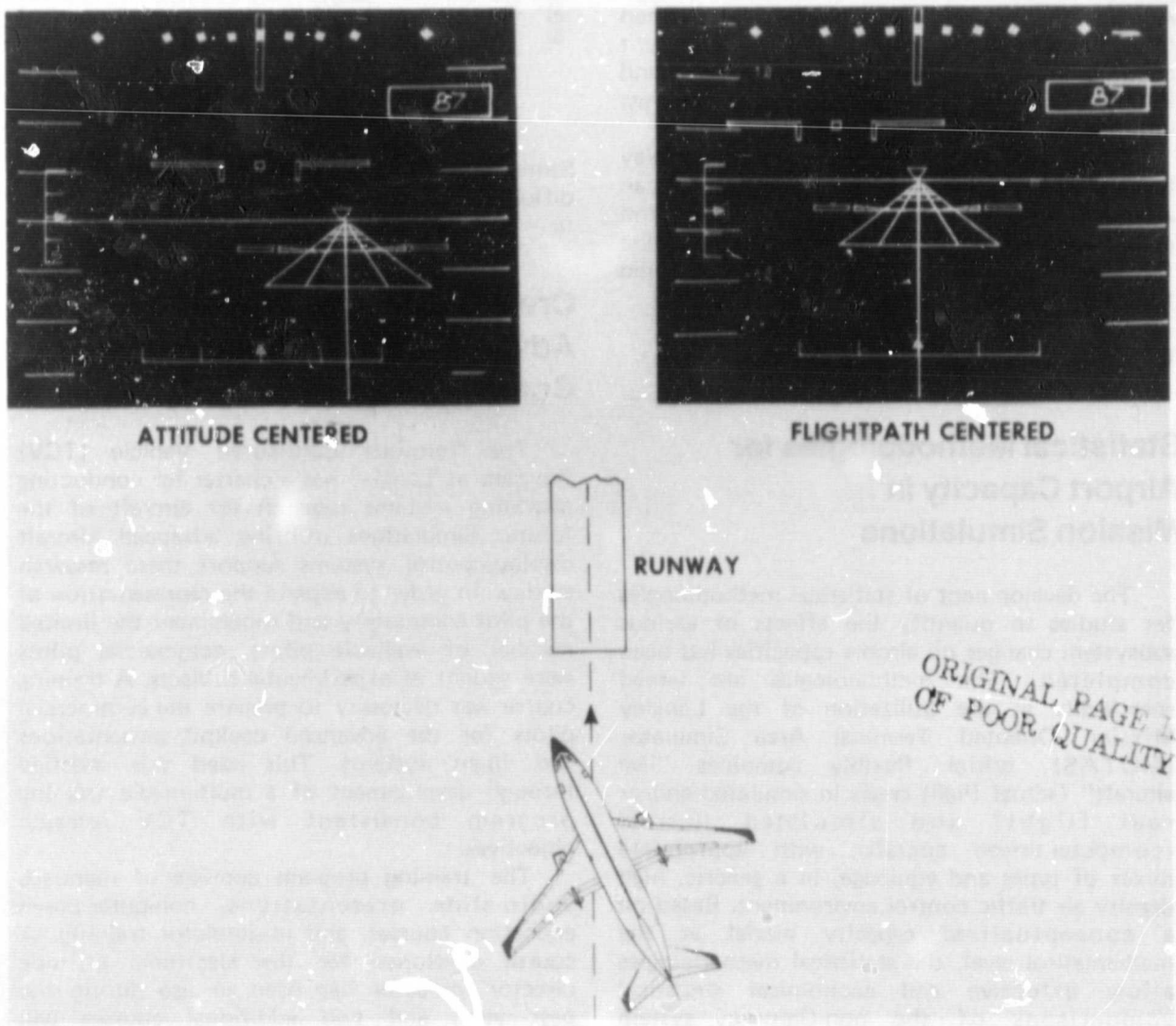
designs the gains for each control actuator are determined essentially independently of each other and entirely new control algorithms are used for different flight maneuvers such as glideslope tracking and flare. By using an integrated control algorithm, DIALS requires few gain changes during the capture, track, and flare maneuvers. In addition DIALS has incorporated several practical constraints such as a conventional crab/decrab maneuver to enhance pilot monitoring capability and an automatic trim feature to reduce the effects of uncertainty and off-nominal conditions.

The DIALS has demonstrated excellent performance in extensive ground-based simulation studies which include nonlinear aircraft aerodynamics, wind models, and detailed sensor noise models including a model of the Time-Referenced Scanning Beam Microwave Landing System used for landing guidance. Based on this performance the DIALS is being implemented on the TCV B-737 for flight test to gather data for performance evaluation and further system development.

Richard M. Hueschen, 3350 (534-04-13)

Improved Cockpit Instrumentation for Transport Operations

The research and development of electronic display concepts that will improve pilot instrumentation for the approach-to-landing task in low visibility have been conducted in both simulation and flight. Computer-based perspective runway images combined with



Cockpit display for transport operations

primary attitude (including flight path angle) information on a cathode ray tube allow curved close-in approaches under instrument flight rule conditions. Computer augmented control of flight path angle combined with an integrated display allows more precise tracking on an approach, yet requires less pilot physical workload.

Traditionally, electromechanical and electronic attitude director indicators (EADI) have been centered about the pitch attitude of the aircraft. With increasing use of track-oriented map displays and EADI's containing flight path angle, a better integration of overall information can be achieved by centering the EADI about the flight path angle presentation. The advantages of the display recentering were confirmed by test pilots in simulation tests, without degradation in flight path tracking or increases in physical workload. Among notable improvements were the reduced display element motion during turbulent conditions, easier correlations between map and EADI, and centering of prime interest information.

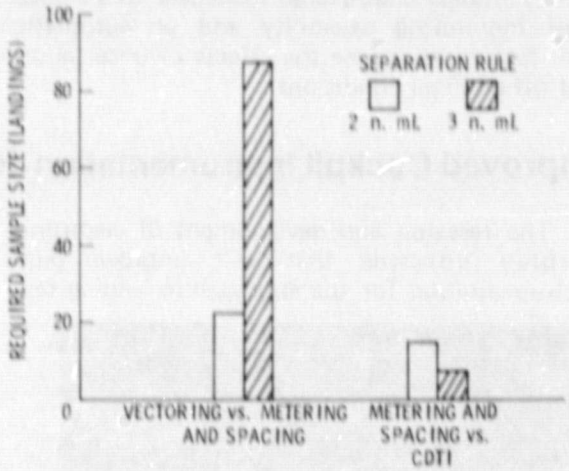
The effects of the recentering of the display format are illustrated in the figure for an approach to landing condition with a crosswind present. Note the subtle alignment effects of the ILS indicators with the extended centerline and flight path angle.

G. G. Steinmetz, 2344 (534-04-13)

Statistical Methodologies for Airport Capacity in Mission Simulations

The development of statistical methodologies for studies to quantify the effects of various subsystem changes on airport capacities has been completed. The methodologies are aimed specifically at the utilization of the Langley Mission Oriented Terminal Area Simulator (MOTAS), which flexibly combines "live aircraft" (actual flight crews in simulated and/or real flight) and simulated aircraft (computer-driven aircraft), with appropriate mixes of types and equipage, in a generic, high density air traffic control environment. Based on a conceptualized capacity model at the mathematical level, the statistical methodologies allow effective and economical statistical comparisons of the non-Gaussian system measures from these very large multi-man/system studies. The figure provides a comparison of experiment sample size required to resolve a capacity change with 95 percent confidence for several traffic control procedures. These results are based on previously published data regarding delivery accuracy for the air traffic control procedures indicated.

R. L. Bowles, 3304 (534-04-13)



Sample size to quantify airport capacity differences
($\alpha = \beta = 0.05$)

Crew Training for Aircraft Advanced Displays and Controls Research

The Terminal Configured Vehicle (TCV) Program at Langley has a charter for conducting operating systems research for aircraft of the future. Simulations utilizing advanced aircraft display/control systems support these research studies. In order to expand the representation of the pilot community and supplement the limited number of available pilots, commercial pilots were sought as experimental subjects. A training course was necessary to prepare the commercial pilots for the advanced cockpit presentations and flight systems. This need was satisfied through development of a multi-media training program consistent with TCV research objectives.

The training program consists of manuals, audio-slide presentations, computer-based education courses, and in-simulator training. A course developed for the electronic attitude director indicator has been in use during the past year, and two additional courses will become available this winter.

In addition to the advanced concepts preparation training of the commercial pilot pool, several spinoff benefits have resulted. These spinoffs include the training and expanded education of engineers and technicians involved in or desiring to support TCV research. In addition, a joint NASA/Navy test pilot school program is underway where students are trained on the TCV systems, thus allowing for better dissemination of technical information to the military. Finally, the course materials and devices have proved to be excellent sources for briefing the aviation communities in regard to TCV advanced display/control systems and operating systems technology.

The training program and accompanying material are available at Langley. The introductory studies, training, and research are normally conducted at the Center, once an applicant is accepted into the program.

PLATO terminals and PLATO Learning Centers (located nationwide as part of Control Data Corporation's PLATO Educational System) can be used to access this program for familiarization and demonstrations after arrangements are made with Langley.

Jacob Houck, 2981 (534-04-13)

Optimum Vertical Flight Profiles

To the commercial air carrier, reduction in fuel usage means reduction in operating costs and an increased profit margin. Increasing labor costs and penalties on air travel time make it desirable to minimize flight time. These factors have motivated the search for a flexible concept for generating a vertical reference profile which minimizes the total cost (fuel and time) of an operation between two airports. Langley has developed two computer programs that will form the basis for the design of an onboard flight management concept that will enable the flight crew, while airborne, to compute and execute changes in the flight profiles due to change in weather conditions or final destination. The first program (OPTIM) is capable of minimizing fuel usage, flight time, or a combination of these variables (direct operating costs). Sensitivity studies will determine the variation in the optimum vertical profile as a function of variations in wind, takeoff weight, and range to destination. Fuel and time costs will be varied to study their effect on total cost and profile definition. The second program (TRAGEN) simulates the vertical trajectory of an aircraft commanded to follow the reference path output from the OPTIM program.

Samuel A. Morello, 3621 (534-04-13)

Composite Components for Commercial Aircraft

Five shipsets of B-727 composite elevators, designed and fabricated under the Aircraft Energy Efficient Composites program, were installed on commercial transport aircraft between February and May. FAA certification of this composite secondary structural component was issued in December 1979. Twelve DC-10 composite rudders are now in flight service with an accumulation of 112,334 flight hours; the high-time rudder has 16,688 hours. Flight check-out of the L-1011 composite aileron has been completed and certification is expected in November 1980. Flight check-out of the first medium primary composite component (B-737 horizontal stabilizer) was completed in September. The L-1011 vertical fin full size ground test articles have been successfully fabricated and fully assembled. The DC-10 vertical fin ground test stub box beam has been assembled and significant advances have also been made in the fabrication of parts for the full size articles.

Herman L. Bohon, 3081 (534-03-13)

Laminar Flow Control (LFC) Technology

Low-speed wind-tunnel tests have been made of boundary-layer suction through woven stainless steel porous surfaces of two different geometries and through an electron-beam perforated titanium surface. Both porous configurations evidenced sufficient inherent surface smoothness to permit attainment of the design extent of laminar flow at conditions approaching flight values. The design extent of laminar flow was also attained with suction through electron-flow perforations of a size smaller than any heretofore attainable. Low-speed wind-tunnel tests of a full-scale leading-edge wing section with suction slots have demonstrated that liquid ejection through slots in the stagnation region is effective in preventing

accumulation of insect residue in the critical leading-edge region and have provided quantitative data on required flow rates. In the area of LFC design tools, a new approach to the analysis of suction through porous strips versus a continuous suction surface is in agreement with experiment in that 5 to 10 percent more suction is predicted; wind-tunnel techniques for flow visualization of Tollmien-Schlichting waves and for simulation of swept-wing cross flow have been developed; and initial analyses of Goertler instabilities (due to concave surface curvature) indicate that large amounts of localized suction are required to control the disturbance growth and that the surface pressure gradient has a strong influence on the suction requirements.

R. D. Wagner, 2045 (534-01-13)

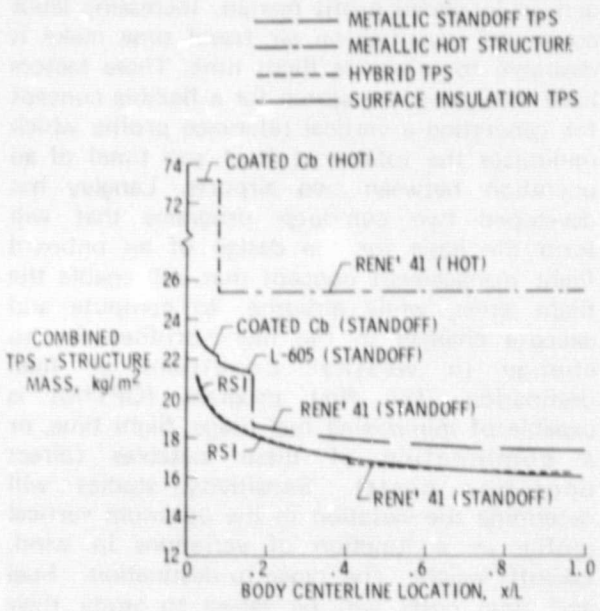
Energy Efficient Transport

A multi-disciplined investigation of the integrated application of active controls to a current technology commercial transport indicates that a reduction in fuel consumption of greater than 10 percent can be achieved using this design approach. In-service flight evaluations of selected coatings applied to the slats and horizontal tail of a B-727 showed that polyurethane coatings were effective in reducing rain erosion damage to aircraft leading-edge surfaces. Analysis and wind-tunnel tests of winglets on a DC-10 have indicated fuel reductions of 3 to 5 percent. Slight decreases in DC-10 flutter speed with winglets have also been identified in wind-tunnel studies; however, structural stiffening of the wing could restore the flutter margin with only a minor weight penalty. Wind-tunnel investigations show that a 10-percent reduction in fuel consumption can be achieved with high aspect ratio supercritical wings within the design constraints imposed by an advanced technology medium range transport. Wind-tunnel investigations of the installation of a long duct nacelle modification to the DC-10 production engine have provided the confidence that this installation can be achieved with minimum interference drag penalty. Analytical studies have shown that when winglets are included in the initial wing design cycle, an optimized wing-winglet design can provide a 1-percent increase in return on investment with respect to an advanced design without winglets.

R. V. Hood, 2396 (534-02-13)

Thermal Protection Systems for Advanced Winged-Entry Vehicles

The impact of aerothermostructure design integration on thermal protection system (TPS) mass for a control-configured single-stage-to-orbit launch vehicle has been examined. Four basic categories of TPS were considered: reusable surface insulation (RSI), metallic hot structure, metallic standoff, and hybrid system (RSI in the hot stagnation regions and metallic standoff in the cooler areas). Entry trajectories were generated which were tailored specifically to each TPS concept in terms of total heat load and peak heat rate and subject to an 1100 n.mi. cross range constraint. These trajectories were used with an aerodynamic heating/thermal analysis program to determine the centerline TPS requirements, assuming laminar flow. Results indicate that for an aluminum structure either the RSI or the hybrid TPS (RSI-Rene' 41 metallic standoff), each coupled with the appropriate trajectory, has the potential to yield the lowest mass system. However, the metallic standoff systems could be quite competitive if possible reductions in panel masses indicated by the on-going research at Langley can be realized. Results also show substantial mass penalties associated with the use of nonoptimum entries for any of the TPS concepts considered. The impact of the utilization of structural materials with higher temperature capabilities than aluminum was also investigated. Significant mass reduction appears



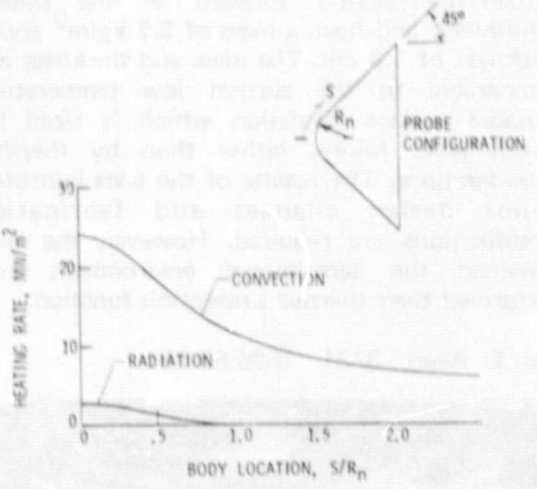
Combined TPS-structure mass requirements

to be available through the use of such materials. Among the materials examined, graphite/polyimide seems to have the potential to yield the greatest mass reduction, partially through reduced TPS requirements and partially through reduced structural mass.

Kathryn E. Wurster, 3911 (506-51-13)

Thermal Analysis for Saturn Entry

A preliminary analysis of the aerothermal environment over a Saturn entry probe has been conducted based on recently defined entry conditions from the Jet Propulsion Laboratory. The nominal trajectory is based on a 45^{o}, spherically blunted cone entering the Saturn atmosphere, 0.89/0.11 H_2/He gas mixture, at a relative entry velocity of 28 km/s with a -30^{o} relative entry angle. Off-nominal conditions were considered to study the effects of changes in entry velocity and atmospheric gas composition. The study defined the primary heat-transfer mode for heat shield design, investigated effects of nonequilibrium chemistry, and delineated some problem areas for future studies.



Saturn probe entry heating

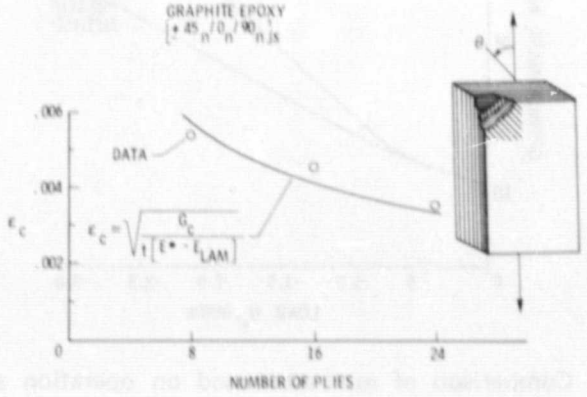
The results showed that the dominant heating mode for nominal entry conditions is convection rather than radiation. Due to the importance of convective heat transfer, a realistic selection of a transition criterion from laminar to turbulent flow may be critical for Saturn thermal studies. For certain off-nominal conditions, radiative heat transfer can be important and there is some uncertainty in the effects of nonequilibrium chemistry on radiative heat transfer. The heat transfer and resulting heat shield mass-loss rates for the currently defined Saturn entry are small compared with values for a Jupiter entry.

E. V. Zoby, 2707 (506-51-23)

Fatigue Delamination of Composite Materials

Recent research at Langley has led to a method to predict conditions that lead to the onset of delamination. Under repeated high loads, structural materials eventually weaken and fail by fatigue. This is true even for fatigue resistant composite materials like graphite/epoxy, which is made from stacked layers of graphite fibers embedded in an epoxy matrix. The fibers in adjacent layers are orientated in different directions, depending upon the desired strength characteristics. A common failure mode in graphite/epoxy is delamination between plies. The strain energy released during delamination was found to be a material constant, G_c (see figure). An analysis, based upon this parameter, resulted in the simple equation shown. It predicts the critical value of strain at the onset of delamination. The other variables in the equation are easily determined: E_{LAM} is the material stiffness with no delamination; E^* is the stiffness after the laminate has completely separated into two parts (total delamination along one interface). Both E_{LAM} and E^* are found from a straightforward application of laminate theory. The thickness, t, is the laminate thickness. After G_c is found from some simple tests, it can be used to predict the strain at delamination onset in graphite/epoxy for any combination of ply layup or laminate thickness, as the figure illustrates.

T. K. O'Brien, 3011 (506-53-53)

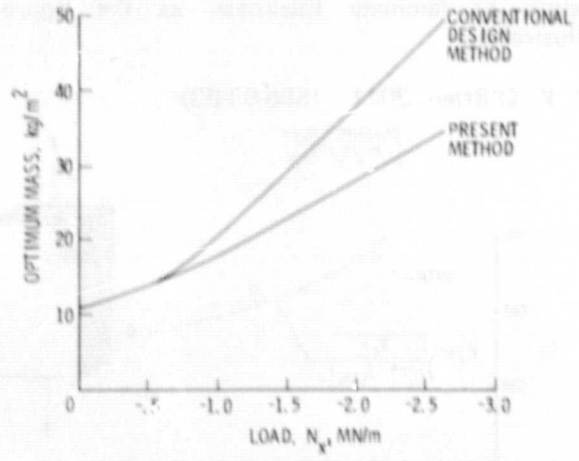


Delamination onset predicted

Analytical Sizing of Insulated Structures

The trend in contemporary design practice for flight structures undergoing high heating associated with atmospheric reentry is to minimize the mass of the structure as well as its thermal protection system (insulation). Toward this end, Langley has developed a procedure for obtaining minimum-mass designs of insulated structural panels. The panels are characterized as consisting of a structural layer and an insulation layer. The panels are loaded by a general set of inplane forces applied to the structural layer and a time-dependent temperature applied to the outer surface of the insulation layer. Temperature and stress histories in the panel are obtained by an exact analysis, and determination of the insulation and structural thicknesses is performed by classical optimization techniques. The computerized procedure is intended for preliminary design calculations, to evaluate materials for specified applications, and to perform parameter studies. The procedure has been applied to design calculations to evaluate the efficiency of a variety of structural materials under combined heating and mechanical loads.

The present procedure is a departure from, and potentially a significant improvement over, conventional design practice, wherein it is assumed that the minimum-mass structure is one which operates at its maximum-use temperature. In the present procedure no such assumption is made. The result of relaxing the assumption is the achievement of lighter designs which operate at lower temperatures where structure strength is higher.



Comparison of methods based on operation at allowable temperature for Lockalloy

H. M. Adelman, 3155 (506-53-53)

Metallic Thermal Protection System

A promising metallic thermal protection system (TPS) concept called "multiwall" has emerged from conceptual design studies at Langley. Multiwall consists of discrete tiles which have multiple layers of dimpled foil connected together dimple-to-dimple. The TPS is currently proposed as part of the orbiter experiment (OEX) program, and is under study as an alternate or second generation TPS for the Shuttle. The OEX program will evaluate the effectiveness of multiwall for Shuttle Orbiter application. A location was selected where the maximum surface temperature is about 800 K so that tiles could be made from titanium.

Titanium multiwall tiles have been fabricated and were recently tested in the Langley 8-foot high temperature structures tunnel. The tiles are designed for a location on the fuselage centerline slightly forward of the pilot's windshield, and have a mass of 3.7 kg/m^2 and a thickness of 1.9 cm. The mass and thickness are comparable to the current low temperature reusable surface insulation which is sized by aerodynamic fairing rather than by thermal considerations. The results of the tests indicated minor design changes and fabrication modifications are required. However, the tiles sustained the aerothermal environment and performed their thermal protection function.

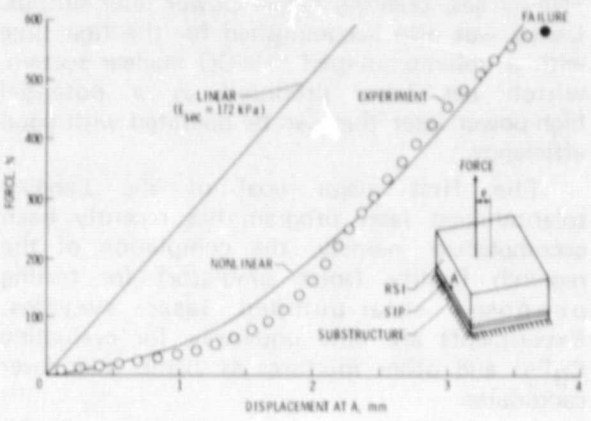
Don E. Avery, 3731 (506-53-73)

Metallic thermal protection systems

Shuttle Tile Analysis Improved

The strain isolation pad (SIP) material used to attach reusable surface insulation (RSI) tiles to the Space Shuttle Orbiter metallic substrate exhibits significant nonlinear stress-strain behavior. Until recently, shuttle tiles were structurally analyzed assuming the SIP responded as a linear elastic material. A more accurate structural analysis was recently developed at Langley in which the SIP material is treated as nonlinear using a series polynomial representation for the stress-strain relationship. Parametric studies using this analysis have shown significant differences between linear and nonlinear solutions for the displacement and RSI/SIP interface stress magnitude for representative shuttle TPS cases. An experimental program established the validity of the nonlinear analysis. Results for displacement response to an eccentrically applied tension load are shown in the figure. The displacement response for the RSI measured at point A compares favorably with the nonlinear analysis. The new structural analysis method will improve understanding of how the tiles behave under operational conditions.

J. G. Williams, 3524 (506-53-33)

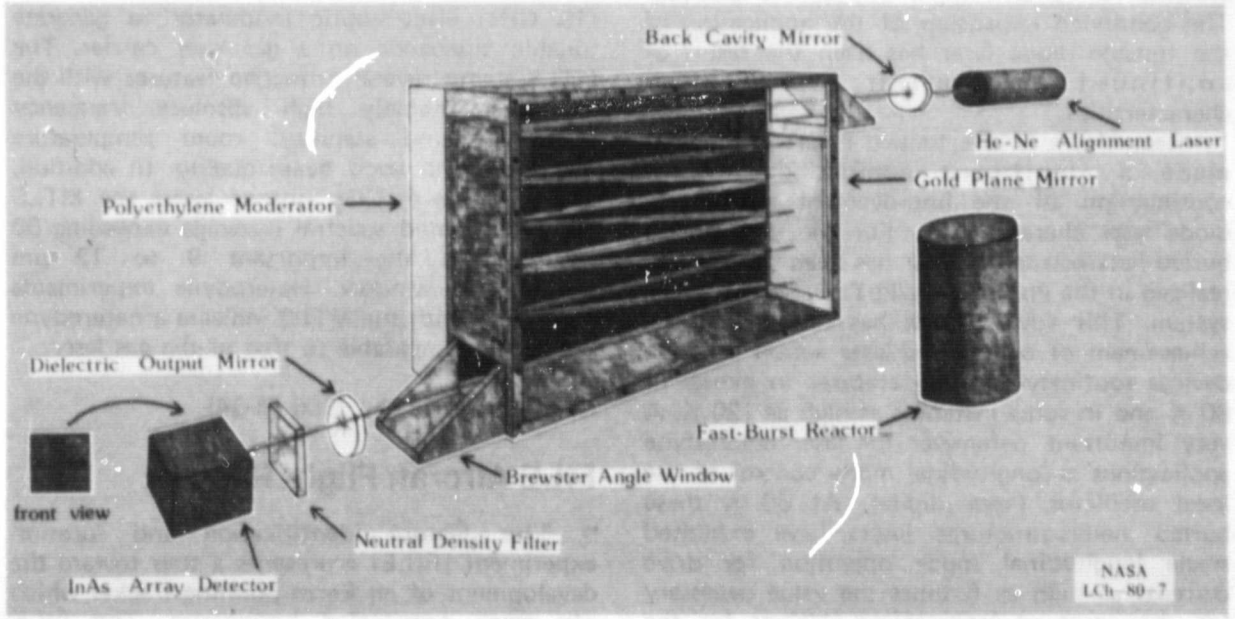


Shuttle tile displacement response

High-Power Lasers for Space Applications

In future decades a number of space missions will require large amounts of energy. There are considerable advantages in supplying this energy in concentrated form over long distances from a central power station. High-power lasers are ideal devices for such purposes because of their directability and small beam spreading. Moreover, only solar- or nuclear-powered laser systems seem realistic for space applications since they alone have the potential for long-term, closed-system operation.

The pumping of gas lasers by charged particles from nuclear reactions has been investigated at Langley for a number of years.



Nuclear pumped multiple pass box laser

One of the major goals has been to demonstrate high-power direct nuclear excited lasing, specifically at the kilowatt level. This goal was recently achieved by using a ^{3}He-Ar mixture in the multipath box laser configuration shown schematically in the figure. The laser beam is reflected back and forth through the excited ^{3}He-Ar gas, creating higher power laser output. Lasing was also accomplished for the first time with a volume-pumped ^{3}He-CO nuclear system, which has been proposed as a potential high-power laser that can be operated with good efficiency.

The first major goal of the Langley solar-pumped laser program has recently been accomplished, namely, the completion of the research facility (solar simulator) for testing proposed solar-pumped laser systems. Experiments are now underway for evaluating C_3F_7I and other mixtures as viable solar laser candidates.

W. E. Meador, 3781 (506-55-13)

New Tunable Diode Lasers for Heterodyne Spectrometry of Gases

Tunable semiconductor diode lasers are finding increased applications in ultrafine gas spectroscopy, monitoring of air pollutants and automotive exhaust emissions, high sensitivity analysis of trace gases in gas mixtures, and more recently in laser heterodyne spectrometer systems for remote upper atmosphere analysis. The continued expansion of the application of the tunable diode laser has been the result of continued improvement of the laser characteristics.

Recently, a NASA funded effort at MIT has made a significant contribution to the continuation of the improvement of tunable diode laser characteristics. For the first time a buried heterostructure laser has been successfully realized in the $Pb_{1-x}Sn_xTe/PbTe_{1-x}Se_x$ materials system. This advancement has resulted in the achievement of continuous laser action of these devices routinely for temperatures in excess of 80 K and in some instances as high as 120 K. A very important parameter for laser heterodyne applications is longitudinal mode control of the local oscillator (laser diode). At 80 K these buried heterostructures lasers have exhibited single longitudinal mode operation for drive currents as high as 6 times the value necessary for the onset of laser action. Values for the onset of laser action (continuous) at 80 K as low as 60 mA have been achieved with this new device. This is the lowest value observed to date for any tunable lead salt laser operating at a wavelength of 9 micrometers and a temperature of 80 K.

This work has provided a new class of tunable diode lasers for use in air pollution monitoring systems and remote upper atmospheric sensing systems.

Carl J. Magee, 3418 (506-56-13)

Infrared Laser for Remote Sensing

The key component in developing a tunable, high performance heterodyne receiver to meet future NASA remote sensing programs is the laser local oscillator. Several IR gas lasers including the CO_2, CO, and N_2O lasers have demonstrated high heterodyne efficiency; however, their discrete tunability restricts their use to chance coincidences with frequencies of interest. Semiconductor diode lasers have wide tunability but operational complexities associated with cryogenic requirements, the need for external frequency identification and control, and laser mode competition problems must be overcome with increased systems complexity.

A new local oscillator approach named the Microwave Tunable Laser Source (MTLS) is being investigated at Langley and has been demonstrated to have some impressive operating characteristics over significant portions of the intermediate IR. The MTLS utilizes a wideband (10 GHz) electro-optic modulator to generate tunable sidebands on a gas laser carrier. The MTLS shares several attractive features with the gas laser, namely high absolute frequency accuracy and stability, room temperature operation, and good beam quality. In addition, when used with CO_2 isotope lasers the MTLS has a calculated spectral coverage exceeding 50 percent in the important 9 to 12 μm atmospheric window. Heterodyne experiments performed with the MTLS indicate a heterodyne efficiency comparable to that of the gas laser.

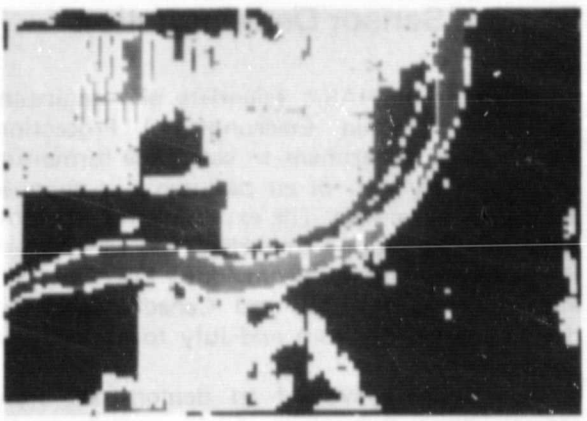
Glen Sachse, 2791 (506-61-54)

FILE Aircraft Flight Results

The feature identification and location experiment (FILE) represents a step toward the development of an Earth pointing tracker which can track preselected boundaries. The FILE itself is designed to automatically, and in real

time, classify scenes into the four categories of vegetation, water, bare earth, and the combined category of snow/clouds/ice. The classification is based on the pixel-by-pixel ratio of the outputs of two charge-coupled device cameras which view the scene through narrow band filters at 0.63 and 0.85 μm. The FILE hardware is one of the experiments on the Shuttle OFT-2 flight. In a precursor aircraft flight during 1980, prototype hardware was flown and preliminary data obtained for assessment. Further data are being obtained over ground truth sites to assess the ultimate capabilities of the system.

R. G. Wilson, 3856 (506-61-73)



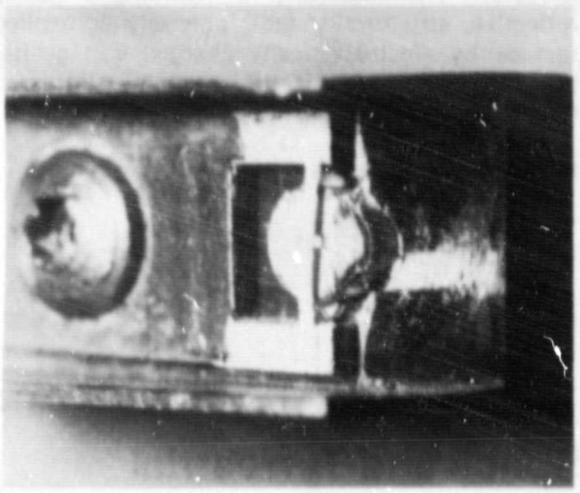
Typical FILE output

LHS Optical Receiver

Langley has developed an optical receiver design concept for the Laser Heterodyne Spectrometer (LHS). This development demonstrated for the first time the feasibility of using a tunable diode laser (see figure) as a local oscillator in the optical receiver of the LHS and represents a significant improvement in state-of-the-art optical receivers. This achievement permits Langley to proceed in its application of the LHS to stratospheric gas species measurement experiments.

Experimental and theoretical investigations performed by this team showed that tunable diode lasers, when properly fabricated and utilized, can form the basis of heterodyne optical receivers which have a spectral resolution an order of magnitude higher than conventional spectrometers. Also, the team demonstrated that the overall instrument performance can yield vertical profiles of trace gas species which are of great importance to the Upper Atmospheric Research Program at Langley.

S. J. Katzberg, 3661 (506-61-53)



Tunable diode lasers

Electrostatically Controlled Membrane Reflectors

The Large Space Systems Technology Program is sponsoring the technology development of electrostatically controlled membrane (ECM) reflectors. The need for high precision reflectors with significant supporting structures to meet stiffness requirements and surface accuracy demands for optical and millimeter wave applications has been studied. Extensive testing at Langley has focused on reducing the reflector's mass by reducing its thickness until it becomes a membrane. A 40- to 60-kilovolt power source on five concentric rings has achieved an acceptable level of distortion as determined by measuring surface control. Research activities have concentrated upon the ECM because of its relationship to the NASA Microwave Radiometer Satellite (MRS). This Earth-oriented measurements mission will provide valuable geophysical data through passive microwave radiometry. An MRS with high spatial resolution has applications for: communications (electronic mail), global crop forecasting (soil moisture sensing), and atmospheric research (radio telescope). Additional missions include long-range weather forecasting and environmental monitoring, such as ocean temperature and salinity shifts, coastal zone parameters, and total ecosphere evaluation.

A Shuttle-launched MRS 50-meter antenna will perform these mission requirements. Tests were designed and conducted on a fabricated 4.88-m-diameter electrostatic membrane reflector. The feasibility of forming a highly reflective, structurally taut, precisely controlled surface by electrostatically charged voltage has been demonstrated at the Langley Research Center.

R. L. James, Jr., 4606 (542-01-13)

Space and Terrestrial Applications

Cloud Cover Analysis Methodology

Quantification of the effects of clouds on the Earth's radiation budget is an important step toward understanding the influence of clouds on the Earth's climate. A comprehensive system of techniques has been formulated to observe the temporal and spatial variability of cloud radiation parameters from geostationary satellite visible (0.5 - 0.7 μm) and infrared window (10.5 - 12.5 μm) radiance measurements. Simultaneous visible and infrared data are analyzed with an energy-balanced, bispectral method. The effective cloud amount for a given measurement may be found through a simple calculation involving the appropriate values provided by the clear sky and cloud models. Models which provide clear sky visible brightness values were developed empirically with a minimum brightness technique. These models account for the variation of reflected radiation as a function of the satellite viewing and solar zenith angles for a given region. Similarly, an empirical reflectance model for optically thick clouds was derived from maximum observed brightness values. The effective cloud top temperature for the region is computed with a single equation utilizing the mean total infrared measurement, effective cloud amount, and the mean effective surface temperatures of the region. Effective surface temperature is determined from infrared measurements corresponding to visible measurements which indicate clear skies. When only infrared data are available, a threshold technique is used to estimate cloud cover. A surface infrared-cooling model was developed empirically to provide hourly effective surface temperatures in this situation. All window-channel measurements are adjusted with a 11.0 μm limb-darkening model. This model was derived theoretically from the results of radiative transfer computations.

E. F. Harrison, 2977 (146-10-06)

Remote Sensor Demonstration

A team of NASA scientists and engineers participated in an Environmental Protection Agency field experiment to study the formation and transformation of air pollutants in regional and urban air masses. The experiment, Persistent Elevated Pollution Episodes and Northeast Regional Oxidant Study, included the combined efforts of several U.S. and Canadian agencies during the period from mid-July to mid-August 1980.

NASA was involved to demonstrate how remote-sensor technology could contribute to the scientific understanding of regional air pollution problems. The major NASA contribution was the first airborne remote measurements of atmospheric mixing layer height and O_3 layering on a regional scale. The Langley-developed ultraviolet differential absorption lidar flew 14 missions aboard the Wallops Flight Center Electra aircraft to measure aerosol backscatter for mixing height determination, as well as ozone distribution in the mixing layer. Also onboard was the high spectral resolution lidar developed by the University of Wisconsin under contract to Langley which measured aerosol and molecular backscatter coefficients. The JPL-developed laser absorption spectrometer also flew 14 missions and measured total ozone burden. In addition, NASA made ground-based meteorological ozone measurements with the JPL scanner microwave system and the Langley tethered balloon. Airborne in situ measurements for remote-sensor truth data and correlation were taken and geostationary meteorological satellite imagery was used for real-time experiment planning.

R. J. Bendura, 2486 (146-20-10)

Measurements of Ozone and Aerosol Profiles

The first remote measurements of tropospheric ozone and aerosol profiles were obtained with the Langley airborne Differential Absorption Lidar (DIAL) system during flight tests between May 22 and June 6, 1980. The DIAL system was operated in a nadir mode from the Wallops Flight Center Electra aircraft operating at a nominal altitude of 3.2 km. An instrumented Cessna 402 aircraft provided in situ correlative ozone measurements during four flights in the vicinity of the Chesapeake Bay. The DIAL measurements of ozone are within 13 percent of the in situ values obtained with the Cessna. Important scientific investigations of regional and global ozone production, transport, and destruction can be conducted with the remote profiling capability of the airborne DIAL system.

Aerosol backscatter profiles were also obtained on several flights. These measurements show distinct features which indicate the location of stable layers in the atmosphere. The thickness of the boundary layer as determined from these measurements agreed with in situ measurements of temperature and dew point. Boundary layer and tropospheric dynamics can be studied using the aerosol distribution information available from the airborne DIAL system.

The airborne DIAL system can provide the necessary high-resolution, synoptic data on ozone and aerosols to dramatically increase our ability to study tropospheric ozone on a regional scale and provide the large-scale coverage required for investigating global budgets of ozone and aerosols.

E. V. Browell, 2576 (146-20-10)

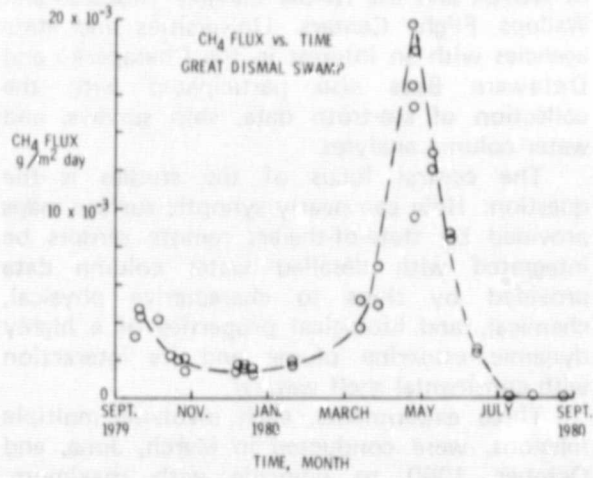
The Global Methane Cycle

The chemical composition of the Earth's atmosphere is profoundly different from what it would be if it were determined only by lifeless geochemical forces. As our understanding of sources and sinks of atmospheric gases such as CO_2, N_2O, and CH_4 has advanced in recent years, it has become increasingly apparent that the biosphere is a primary factor controlling atmospheric chemistry. A research program at Langley seeks to quantify the linkage between the ecology of methane production and the global cycle of this trace gas which is critical to both chemical and radiative transfer processes in the Earth's atmosphere.

Methane is produced by methanogenic bacteria living in habitats devoid of oxygen. The major areas of anaerobic habitat on the Earth and in contact with the atmosphere are wetland ecosystems such as swamps, peat bogs, and flooded agricultural soils (e.g., rice fields). Wetland habitats are perhaps the most vulnerable ecosystem on Earth to the stress of economic development pressures. Swamps are being drained for agricultural development and peat bogs are becoming increasingly important as a potential energy source. Thus, our present state of knowledge leads to several critical unanswered questions: How important are various types of wetland ecosystems as a source of global atmospheric methane? What are the major physical factors which determine the temporal and spatial character of methane emissions from wetlands to the atmosphere? Will the loss of wetland habitat on a global scale lead to changes in the global properties of the atmosphere?

Langley results obtained by a detailed investigation of methane emissions from the Great Dismal Swamp, Virginia, demonstrate a large seasonal variability in methane production rates which is highly correlated with the decomposition cycle of forest leaf debris and levels of soil moisture. Such data are critical to the development of a strategy for assessing linkages between the biosphere and atmosphere on a global scale.

R. C. Harriss, 3645 (146-20-10)



Methane emission from the Great Dismal Swamp

Trace Gases Increase Sulfate Formation on Carbon Surfaces

The oxidation of SO_2 to sulfates on the surface of carbon particles has been studied in the presence of several atmospheric trace oxidants: N_2O, NO, NO_2, O_3, and H_2O_2. Carbon particles are, of course, present in the atmosphere in the form of soot. The results obtained, therefore, have applicability to the phenomenon of acid rain, a major constituent of which is sulfate.

The trace gases N_2O and NO have been found to have no significant effect on the oxidation of SO_2 on carbon. However, NO_2, O_3, and H_2O_2 have been found to significantly increase the conversion of SO_2 to sulfates on carbon. The yields of sulfates produced when SO_2 and NO_2, O_3, or H_2O_2 in a nitrogen carrier react on carbon particles exceed those produced when SO_2 and air react on such particles, even when the concentration of the trace oxidants is as low as 70 parts per billion. Sulfate formation is further increased when the trace gases are humidified or when they are bubbled into a suspension of carbon in liquid water.

David R. Schryer, 2818 (146-20-10)

Chesapeake Bay Plume Studies

The 1980 Chesapeake Bay Plume Studies were a joint endeavor of the Northeast Fisheries Center of the National Marine Fisheries Services of NOAA and the NASA Langley Research and Wallops Flight Centers. Universities and state agencies with an interest in the Chesapeake and Delaware Bays also participated with the collection of sea-truth data, ship surveys, and water column analyses.

The central focus of the studies is the question: How can nearly synoptic surface maps provided by state-of-the-art remote sensors be integrated with detailed water column data provided by ships to characterize physical, chemical, and biological properties of a highly dynamic estuarine plume and its interaction with continental shelf waters?

Three experiments, each involving multiple missions, were conducted in March, June, and October 1980 to coincide with maximum, intermediate, and minimum freshwater input, respectively. This was a major accomplishment in that NASA remote sensors with proven capabilities for oceanographic measurements of temperature, salinity, chlorophyll *a*, fluorescence, turbidity, and color were flown as an integrated system taking simultaneous data in a series of experiments designed around specific oceanographic objectives.

Janet W. Campbell, 2871 (146-40-15)

Algae Ocean Color Spectral Signatures

The synoptic character of remote sensing of ocean color changes caused by pollution is of particular interest in assessing environmental quality. Langley research has shown how laboratory-generated spectral signatures can be used to interpret this remotely sensed data.

Ocean fronts related to ocean processes and algae blooms indicating productivity of the fisheries are areas where remote spectral sensing can make significant contributions. Continuing investigations at Langley provide basic information and data for the interpretation of ocean color through use of laboratory spectral signature measurements that are related to real ocean color.

Studies of the spectral optical characteristics of three cultured, tank grown, salt-water algae representing golden brown, blue-green, and green phytoplankton species have been performed. Spectral upwelling radiance and spectral sky irradiance were measured outdoors for each cultured algae tank to obtain spectral reflectance curves over the 400 to 800 nm wavelength range. Measurements were made during algae life cycle growth to bloom and die-off phases.

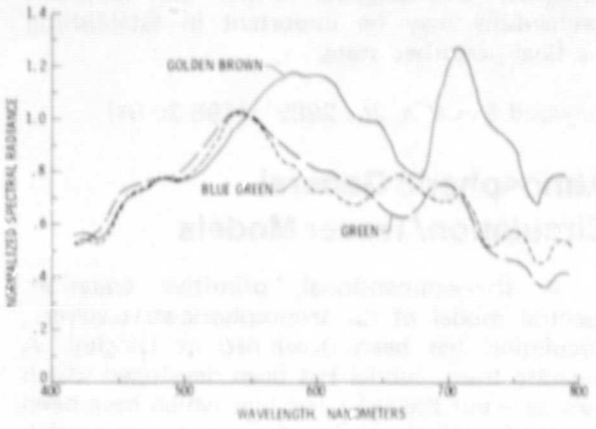
Changes in algae concentration with growth generally gave radiance changes in intensity rather than color. Spectral changes were observed in the die-off phases where shifts in spectral peaks occurred. At one stage, where inorganic sediment was incrementally added to assess its effect on upwelling radiance, only intensity increases were observed with no color changes. Corresponding samples were removed from the tank for measurement of spectral transmittance, algae cell count, and concentration of chlorophyll-*a* and suspended solids.

The spectral radiance (reflectance) curves for each algae were different enough to distinguish unambiguously between the three (see figure). The data obtained were used to predict the

effect of each of the algae and their changes on the remotely sensed spectral upwelling radiance (color) of ocean waters of several types through application of a simplified, low altitude remote sensing radiometric model.

This work demonstrates that laboratory measurements provide the basic information to assess the inherent remote-sensing capabilities of a particular substance in ocean waters. This type of data and analysis, obtained from controlled laboratory tests, is of use for establishing quantitative relations between color and algae concentration or condition.

B. W. Lewis, 2065 (146-40-15)



Spectral upwelling radiance from three color types of algae

Optical Properties of Turbid Waters

Heretofore, it has generally been accepted that the amount of backscattered sunlight from turbid waters is a direct measure of the amount of suspended particulates in the water. While this rule applied to four or five rivers (e.g., Savannah River) studied by the Langley Optical Physics group in their November 1979 Georgia experiment, the St. Mary's River was an anomaly. It was comparatively high in total suspended particulates but had the lowest upwelled radiance. The reason was believed to be the presence of dissolved organic carbon (DOC) because this river had the highest level of DOC of the five rivers. A laboratory simulation of the St. Mary's River water, in the Spectral Signature Laboratory at Langley, demonstrated quantitatively for the first time that DOC acted as a strong absorber. In the presence of clay particulates, the net effect was a reduction in backscattered light despite large quantities of suspended particulates. These results are of critical importance in developing remote sensing systems to provide needed data on mass and nutrient transport into oceans.

Charles H. Whitlock, 2871 (146-40-15)

Aircraft Remote Sensing of Hurricanes

A joint NASA-NOAA program to obtain microwave measurements of the sea surface during the passage of a hurricane has yielded results important to the study of hurricanes. Instruments and scientists from Langley flew into Hurricane Allen on August 5 and 8, 1980. On board the NOAA C-130 Hurricane Hunter aircraft were a stepped-frequency microwave radiometer and a steerable microwave scatterometer, both developed at Langley. The radiometer measures brightness temperature of the sea surface at several frequencies, and the scatterometer determines the scattering coefficient of the sea surface at various azimuths and incidence angles. Penetrations were made of Hurricane Allen at 1500 to 3000 meter altitudes, well above the dangerous turbulent layer near the sea surface. A second NOAA aircraft made near-simultaneous penetrations at altitudes within the turbulent layer.

Preliminary data from the radiometer yielded empirically derived rainfall rates and wind speeds virtually identical to those obtained in situ with the low-flying aircraft. And, except in regions of high rainfall, a first inspection of the scatterometer data allowed estimation of wind speeds up to 35 m sec^{-1} and of wind direction at all wind speeds. These results may lead to the transfer of the Langley-developed technology to NOAA for possible elimination of the risky low-altitude hurricane flights.

Plans for future years include development of algorithms for improved calculation of rainfall rate and wind vector, and of an airborne processor to allow these calculations to be made real-time. The results would then be displayed to scientists aboard the aircraft and also transmitted to the National Hurricane Center in Miami.

R. F. Harrington, 3631 (146-40-05)

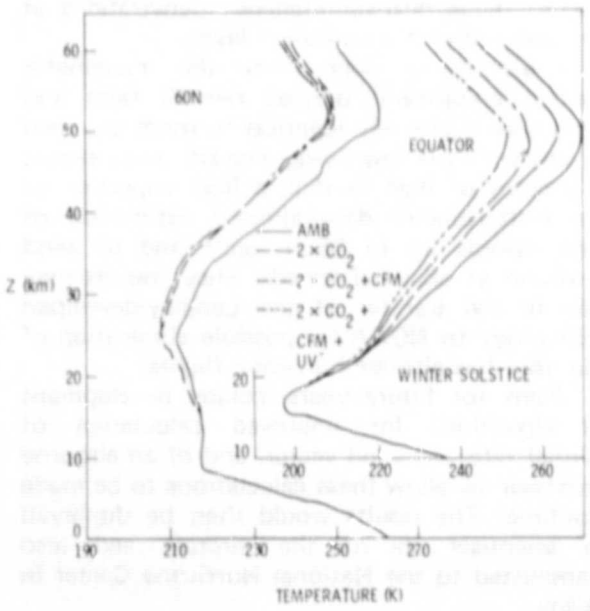
Stratospheric Ozone and Temperature Perturbations

Atmospheric injection of chlorofluoromethanes (CFM's) and carbon dioxide (CO_2) can cause thermal and chemical perturbations in the stratosphere. Calculations suggest that stratospheric temperatures and ozone (O_3) may be reduced by 14 K and 30 percent, respectively, due to combined atmospheric CO_2 and CFM increases.

An important question not heretofore addressed is whether or not significant dynamic changes occur as a result of such thermal perturbations. This is important from the point of view of understanding the impact of atmospheric increases of CFM's and CO_2 on the stratospheric dynamic climatology and on the distribution of stratospheric trace constituents.

To resolve this question, a Langley-developed radiative-convective model was used to calculate the stratospheric temperature structure for Northern Hemisphere wintertime at solstice conditions for latitudes from the equator to 75°N. The calculations were carried out for ambient conditions, for time-dependent release scenarios for both CO_2 and CFM's, and for an assumed solar flux distribution corresponding to solar minimum conditions.

Results are shown on the accompanying figure which illustrates temperature profiles for 60°N and the equator. At the equator, all the perturbations significantly affect the temperature structure. At 60°N, only the CO_2 has an appreciable effect. This is due to the low values of the solar heating due to O_3 and to the large (relative to O_3) infrared cooling rate of CO_2 at the higher latitudes. The result is a change of the stratospheric latitudinal thermal gradient which is a determining factor in the establishment of the stratospheric zonal winds. Use of the thermal wind equation suggests that the changes shown in the figure will result in a 16 to 20 percent decrease in the stratospheric zonal wind at 50 km. These changes may be significant with respect to planetary wave configuration and, hence, minor constituent transport. This suggests further that feedback mechanisms may be important in establishing the final perturbed state.



Effects on latitudinal temperature structure

Linwood B. Callis, Jr., 2985 (198-30-01)

Atmospheric General Circulation/Tracer Models

A three-dimensional, primitive equation, spectral model of the tropospheric-stratospheric circulation has been developed at Langley. A separate tracer model has been developed which uses as input the field variables which have been previously calculated by the circulation model. Results obtained during a winter simulation conducted with the circulation model demonstrate good agreement with observed January mean climatology. Results have also been obtained for transport of a passive tracer initially injected into the stratosphere. These models will be used to study atmospheric transport processes and to simulate the spatial and temporal variations of both passive and chemically active constituents. These studies will complement NASA satellite measurement programs and aid in the interpretation and analysis of the acquired data.

William L. Grose, 2039 (198-30-02)

First Satellite Measurements of Stratospheric Ozone-Nitrogen Chemistry

Theoretical and laboratory studies have indicated that catalytic chemical reactions between ozone and oxides of nitrogen could

cause significant perturbations to stratospheric ozone concentrations. The Limb Infrared Monitor of the Stratosphere (LIMS) experiment was launched onboard the Nimbus 7 satellite on October 24, 1978, to study the impact of oxides of nitrogen on stratospheric ozone by collecting and analyzing data on a global scale. LIMS measured radiances from the Earth's limb during both day and night which were used to infer upper atmospheric temperature profiles and concentrations of key chemical compounds that are important in the ozone-nitrogen chemistry. These measurements included ozone (O_3), water vapor (H_2O), nitrogen dioxide (NO_2), and nitric acid (HNO_3). The experiment functioned virtually without flaw over its design lifetime of slightly more than 7 months, returning approximately 7000 radiance profiles per channel each day. The LIMS viewing geometry from the spacecraft was such that the experiment took measurements over about 95 percent of the Earth's surface while covering the range from 64°S to 84°N latitude.

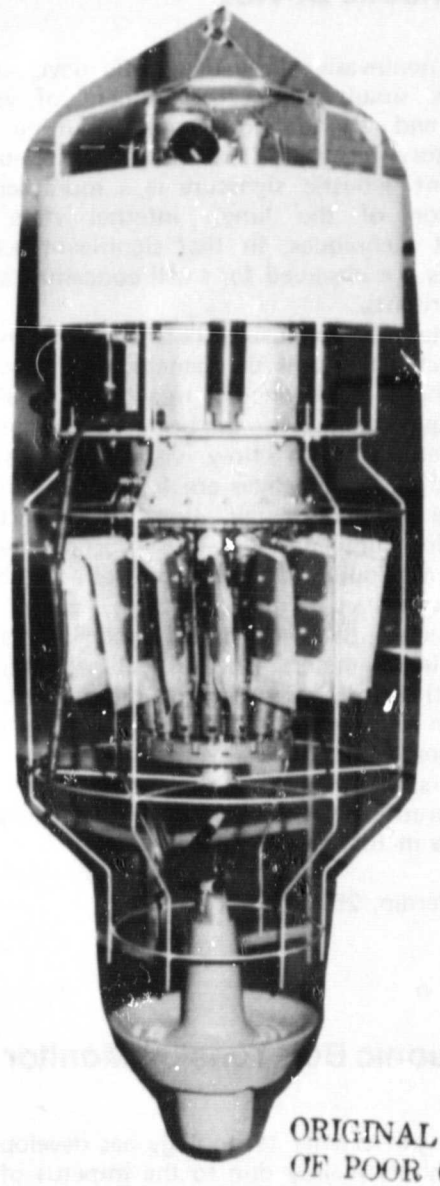
All radiance archive tapes from LIMS have been placed in the National Space Sciences Data Center archive at the Goddard Space Flight Center, thereby making them available to the scientific community. The on-orbit indicated precision of LIMS measurements has been determined and extensive comparisons have been made of LIMS parameters with data measured by independent methods from balloons, aircraft, and rocket underflights. Preliminary scientific results show large diurnal variability for NO_2, small spatial variability in H_2O, the ability of the experiment to sound the O_3 profile from 65 km down to the upper troposphere, and large latitudinal variability in HNO_3 concentrations. This unique data set is providing the critical information required to assess the impact of oxides of nitrogen in stratospheric ozone.

J. M. Russell, 2576 (655-10-40)

Water Quality Monitoring System

In August 1980, Langley performed a successful evaluation test of an automated, in situ, subsurface, water quality monitoring system. The test was conducted jointly with EPA in Lake Huron to demonstrate the automated system developed by Langley.

The system is a programmable in situ monitor that can take data from up to 10 specific water quality sensors and control a 16 cell water sample. The system can measure and record up to 12,000 data points completely unattended over a period of up to 14 days. Immediate measurements, program changes or updates, sensor reading schedules, data retrieval, and buoy recovery can be commanded from a surface unit over wireless acoustic link. All measurements, computations, and display functions are performed automatically within the system. Data reduction, including interactive sensor influences, and the sorting of results up to and including the presentation of results are performed internally. Calibration of the electronics instrumentation is regularly checked by means of an automatic self-test routine. All



Subsurface buoy system

data are recorded in a nonvolatile magnetic bubble memory in the subsurface buoy system (see figure). At the end of the deployment period, an acoustic command is used to release the buoy from its underwater anchor. The complete system was delivered to the EPA at Grosse Isle, Michigan, at the conclusion of the test.

Charles G. Saunders, Jr., 3581 (141-95-01)

Noninvasive Lung Diagnostic Device

A noninvasive lung diagnostic device which enables simultaneous measurement of volume flow and sound production resulting from expiratory respiration has been developed. The resultant acoustic signature is a more sensitive indicator of the lung's internal state than present techniques, in that significant acoustic changes are observed for small concentrations of lung irritants.

Data obtained using the instrument may be interpreted in terms of diameters and flow rates throughout the bronchial tree by an analytical technique developed as part of the project. Observations from flow visualization studies show that four vortices are formed within each bronchi containing air flow in a particular Reynolds number range. These vortices oscillate about an equilibrium position resulting in the generation of narrow band sound. The frequencies of this sound then yield the bronchial diameters (the critical parameters of interest) from the measured volume flow rate, through the theoretical relationship derived in this research.

This work is being carried out in collaboration with the Medical College of Virginia in Richmond, Virginia.

J. C. Hardin, 2617 (141-95-02)

Ultrasonic Bolt Tension Monitor

Critical fastener technology has developed in recent years mainly due to the impetus of new instruments designed for setting or measuring fastener load. Torque traditionally has been the accepted method for obtaining fastener preload. However, measuring torque can lead to significant errors, since up to 90 percent of the applied torque can go into fastener friction leaving only 10 percent for establishing preload. For such a case, a 10 percent change in the coefficient of friction could lead to a 100 percent preload error.

An ultrasonic device, which measures fastener strain directly and is insensitive to friction, has been developed at Langley for setting the preload of roof support bolts used in mines. This instrument allows roof bolts to be tensioned much more accurately than by conventional torque techniques, thus contributing to increased mine safety.

A successful demonstration test was conducted in September 1980 in the Colorado School of Mines Experimental Mine, Idaho Springs, Colorado.

Joseph S. Heyman, 3418 (141-95-01)

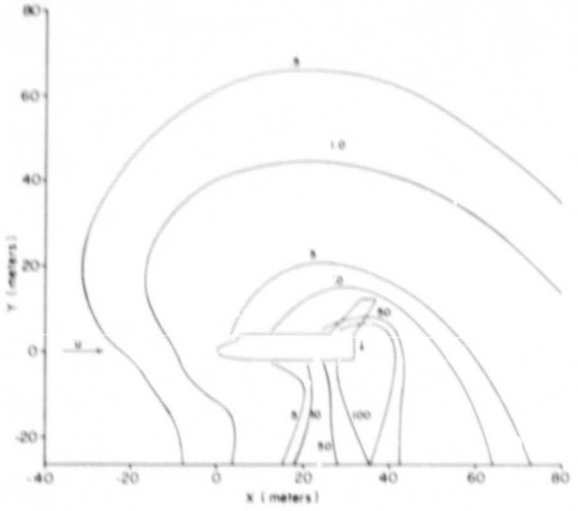
Space Transportation Systems

Shuttle Flow-Field Analysis

A Monte Carlo analysis of the Space Shuttle flow field has been developed and used to predict total density contours normalized to the undisturbed free-stream density in the vicinity of the Shuttle. This is the most rigorous analysis yet developed to predict the distribution of contaminants in the vicinity of the Orbiter during orbital operations. Many gas sources

contribute to these total density contours, including free-stream gas, surface outgassing, and exhaust from a vernier, aft downward-firing engine. The density below the engine is more than 2 orders of magnitude greater than free stream, and the density aft and above the bay exceeds 50 times the free stream. These results emphasize the need to select proper Shuttle operation modes in order to avoid contamination of sensitive scientific instruments.

L. T. Melfi, 3031 (906-75-26)



Normalized total density distribution in the Shuttle midplane